A STUDY OF PILOT ATTITUDES REGARDING THE IMPACT
ON MISSION EFFECTIVENESS OF USING NEW COCKPIT AUTOMATION
TECHNOLOGIES TO REPLACE THE NAVIGATOR/WEAPON SYSTEM OFFICER/
ELECTRONIC WARFARE OFFICER

THESIS

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AFIT/GLM/LSR/91S-62

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degrees of

Master of Science in Logistics Management and

Master of Science in Systems Management

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September 1991

Approved for public release; distribution unlimited

Preface

The purpose of this study was to examine the impact on mission effectiveness of using new cockpit automation technologies to replace the Navigator/Weapon System Officer/Electronic Warfare Officer (Nav/WSO/EWO) in Air Force aircraft. The Air Force appears committed to using the latest technologies as a means to cut personnel costs by trading "black boxes" for aircrew members. The target for the advanced cockpit technologies is the Nav/WSO/EWO, depending on the aircraft.

Our initial beliefs entering into this research project were that the latest cockpit technologies could not _effectively_ replace the Nav/WSO/EWO and maintain the same level of combat mission effectiveness. To test our beliefs, we surveyed 404 Air Force bomber, fighter, transport, air-to-air refueling, and tactical attack pilots. The sampled pilots identified factors that are always critical and almost always critical to combat mission effectiveness. Generally, the always critical factors were similar for almost all aircraft types. The sampled pilots then gave their opinion of the Nav/WSO/EWO's impact on accomplishing the always critical mission effectiveness factors and the Nav/WSO/EWO's impact on overall mission accomplishment. Generally, except for single-seat fighter and attack pilots, the surveyed pilots felt the Nav/WSO/EWO was critical to accomplishment of critical mission factors and overall mission success. Many pilots stated the Nav/WSO/EWO cannot be replaced by advanced cockpit technologies.

We would be remiss if we did not thank the people who made our research effort possible. First, our families--they provided support and understanding as we endeavored to accomplish research that is both professional and credible. Second, we would like to thank our advisor, Dr. Kirk Vaughan. His guidance kept us on an even course throughout the research process. We also owe a debt to Dr. Guy Shane and Maj Wayne Stone for their help in our understanding of applied statistics.

Finally, we want to thank the pilots who took the time to answer our questionnaire. Many of them had just returned from combat operations in the Persian Gulf and their responses indicate that they possess strong convictions about the issues addressed in our research topic. Our goal is to accurately and truthfully interpret their survey responses with the hope that this research will have an impact on future aircraft crew configuration decisions.

William K. Starr and Donald A. Welch

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Abstract

This study analyzed the self-reported survey responses of 404 Air Force pilots concerning their perceptions of using advanced cockpit technologies to replace the Navigator, Weapon System Officer, and Electronic Warfare Officer (Nav/WSO/EWO) and the impact of advanced cockpit technologies on combat mission effectiveness. The first objective of this study was to compare, by aircraft type, the mission effectiveness factors that are always critical and almost always critical to the success of a combat mission. The second objective was to examine, from the pilot's point of view, the Nav/WSO/EWO's contribution (NAVCRIT) to enhancing the combat mission effectiveness factors. The third objective was to examine the Nav/WSO/EWO's contribution (REQ) to overall combat mission success. A stepwise regression model for predicting NAVCRIT and REQ utilizing surveyed pilot demographics was also explored. Research conclusions were mixed--aircraft type impacted on almost all results. Mission effectiveness factors that were always critical were, however, similar across all aircraft types. Examination of NAVCRIT and REQ revealed distinct differences, by aircraft type, of the pilot's perception of Nav/WSO/EWO contribution to combat mission effectiveness.

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I. Introduction

Chapter Overview

This chapter contains general background information relating to issues involving new cockpit automation technologies in U.S. Air Force combat aircraft and their impact on the navigator/weapon systems officer/electronic warfare officer (Nav/WSO/EWO) aircrew position. The specific research problem statement is introduced as well as the research questions, investigative questions, and hypotheses. Also included in this chapter are a description of the scope of the study and pertinent assumptions.

Background

There is an ongoing discussion among Air Force leaders, scientists, engineers, and flight crew members concerning the impact on combat aircraft mission effectiveness of replacing the navigator/weapon systems officer/electronic warfare officer (Nav/WSO/EWO) with new cockpit automation technologies (CAT). New technologies now automate the cockpit duties once performed by the Nav/WSO/EWO, the position to be eliminated. The pilot or pilot/copilot combination is now capable of accomplishing navigation duties with the aid of sophisticated avionics. The new advanced avionics not only yield personnel cost savings by reducing the size of the aircrew but also increase the precision and ease of operation for tasks accomplished by the remaining crewmembers. In addition, the automatic systems are proposed to moderate the demands placed on the remaining crewmembers. Many civil transport aircraft now operate with two, rather than three, crewmembers (26:1). However, U.S. Air Force aircraft must be prepared to operate in complex combat environments where aircrew survival and destruction of enemy targets are critical. Demands placed on pilots/aircrews in a combat environment will be great, and combat mission effectiveness may be impacted if the size of the aircrew is reduced as a result of excessive reliance on automated aircraft systems. If U.S. Air Force aircraft operated exclusively in a non-hostile environment, there probably would be little debate on the merits of increased cockpit automation within the Air Force community. However, the debate on increased cockpit automation and its impact on aircrew size continues, especially as the successes of Operation Desert Storm are analyzed.

Opinions vary on the degree to which the Air Force should replace the Nav/WSO/EWO with advanced cockpit technologies. On one end of the spectrum of this argument are individuals proposing to completely eliminate the navigator career field. They claim technology can enable the pilot(s) to accomplish the duties once accomplished by the Nav/WSO/EWO without degrading mission effectiveness, therefore eliminating the requirement for the extra person in the cockpit. Because technology has the potential to replace the need for the Nav/WSO/EWO in the cockpit, they argue the military can no longer afford to train and maintain individuals in this position. It is costly to recruit, train, and support the Nav/WSO/EWO, and the additional weight of the person and required support systems detracts from aircraft performance (17:13).

In contrast, others argue technology should not completely replace the Nav/WSO/EWO, but should be used to enhance the performance of the Nav/WSO/EWO to increase mission effectiveness. Supporters of this viewpoint believe the impact on mission effectiveness of eliminating the Nav/WSO/EWO is difficult to quantify. They argue mission effectiveness may unknowingly be sacrificed during periods of high pilot workload in a high threat environment. To support their argument they use testimony from pilots who routinely admit they turn off the aircraft warning and information systems in stressful situations to avoid becoming hopelessly confused (30:34). They believe the requirement for a Nav/WSO/EWO in the cockpit depends on the type of mission performed by an aircraft.

Regardless of the optimum choice, one needs only to examine current Air Force initiatives for designing and retrofitting the cockpits of its combat aircraft to determine the course on which the Air Force has embarked. All new aircraft currently under development by the Air Force, such as the B-2, C-17, and the Advanced Tactical Fighter (YF-22), have been designed to operate without a Nav/WSO/EWO. In addition, proposals are being considered by the Air Force to retrofit older aircraft with new cockpit automation technologies. Strategic Air Command (SAC) is considering a proposal to redesign the cockpit of the KC-135 air refueler which would eliminate the navigator. In addition, Military Airlift Command (MAC) is also studying a proposal to redesign the C-130 cockpit, eliminating the navigator and flight engineer positions.

Only one aircraft has been designed in the last decade to incorporate the Nav/WSO/EWO position. The F-15E Strike Eagle is the two-seat all-weather dual role fighter of the tactical air forces (TAF). The F-15E was designed to perform air-to-ground and air-to-air roles (dual role fighter). The U.S. Air Force decided the complexity of the two missions warranted an additional crewmember (32:630).

In spite of the trend to eliminate the Nav/WSO/EWO on most aircraft, in 1987 General Dynamics issued a report that studied a one-seat F-16R fighter compared to a two seat F-16R. The F-16R was a proposed tactical reconnaissance version of the F-16 intended to replace the aging RF-4C. This report illustrates the confusion present surrounding the issue of replacing the Nav/WSO/EWO with advanced cockpit automation technology in that it recommended a two-seat version (23:Executive Summary).

The decision to replace the Nav/WSO/EWO is not a simple and straight-forward one. The decision involves a trade-off between personnel cost savings on one hand and a potential impact on combat capability on the other. Reduction in operational costs over the lifetime of the weapon system is the primary reason for eliminating the Nav/WSO/EWO position in aircraft cockpits (12:1; 30:64; 27:1). The Air Force's desire to reduce personnel costs becomes even more significant when considering current congressionally-mandated force reductions. As the Air Force attempts to meet projected force reductions in the next few years, the motivation to eliminate personnel will become even more acute. The cost of a person in the cockpit in comparison to the cost of new technologically advanced equipment can be calculated fairly accurately. Once the costs are known, the savings can be calculated among the options over future years and a cost analysis can be accomplished. The components of personnel cost are wages, training, retirement pensions and benefits, and various other benefits, such as medical, commissary, and life insurance. Some of the components of equipment costs are design, manufacturing, reliability, redundancy, and maintainability.

Impact on Combat Mission Effectiveness

What is not easily assessed is the impact on combat mission effectiveness of replacing the Nav/WSO/EWO with modern cockpit technology. Part of the problem stems from the fact that a single precise definition of combat mission effectiveness does not exist. The term combat mission effectiveness conveys different meanings to different people. One major distinction among definitions of combat mission effectiveness is the type of consequence or outcome selected as the effectiveness criterion. The outcomes include such diverse factors as ability to avoid a threat, ability to destroy a target, ability to fly safely, ability to operate with degraded equipment, and ability to fly low level at night. The selection of appropriate criteria of combat mission effectiveness appears to depend on the objectives and values of the person or agency making the evaluation. The commander-in-chief of allied air forces in Desert Storm would likely select different criteria than the pilot actually flying the aircraft. In addition, the criteria for combat mission effectiveness may differ among pilots of different aircraft.

It seems plausible to assert that mission effectiveness and the criteria used to measure it are scenario-dependent. For example, the criterion selected to define mission effectiveness would differ for an aircraft performing a peacetime training mission and the same aircraft performing an actual combat mission. For the purposes of this research, mission effectiveness will be used in the context of a high threat combat environment and will be used interchangeably with combat mission effectiveness.

Another dimension to the problem is how to determine the impact of Nav/WSO/EWO's on combat mission effectiveness or, more specifically, how they may or may not enhance the criteria used to define combat mission effectiveness. Analyzing the missions flown in an actual combat scenario would be the only true approach to measuring the impact of the Nav/WSO/EWO on mission effectiveness. To accurately measure the impact, one would have to compare the performance of aircrews on a particular aircraft including a Nav/WSO/EWO to the performance of aircrews on identical aircraft with updated cockpit technology not including a Nav/WSO/EWO. Because this type of comparison is not feasible, attempts to study the impact of replacing the Nav/WSO/EWO have focused on the use of cockpit mockups and simulators to measure aircrew workload.

Crews are tested in cockpit mockups and simulators which incorporate new cockpit designs but which lack the Nav/WSO/EWO. The typical study directs the pilot or pilot/copilot combination to fly either one or more different mission scenarios, with each scenario incorporating various phases of flight for a particular aircrafts mission (14:8; 43:17-25; 12:4). The procedures used by researchers to measure workload are grouped into four major categories: (1) Primary task performances which focus on the degree to which humans achieve stated goals, (2) Secondary task approaches which have been used to assess the amount of operator spare capacity, (3) Physiological techniques, both classical (e.g., heart rate) and specialized (e.g., heart rate variability or evoked potential), and (4) Subjective methods that examine operator experience and include rating scales as well as questionnaries and interviews which continue to be examined as to their most appropriate application in workload assessment (25:2-11). Pilot performance is measured by comparing actual aircraft performance data to ideal flight parameters and plotted over time. The plotted performance is used to analyze the overall workload by supporting or opposing subjective measurements made by the aircrew and observers (35:19).

The results of workload studies have been mixed (10:1-6; 28:168-1/2). Most studies have concluded that the ability to fly the mission effectively without a Nav/WSO/EWO depends on the complexity of the mission. The requirement to accomplish increasingly complex missions at night and/or in poor weather conditions strains the ability of a reduced crew to effectively accomplish its tasks. Complex mission profiles are designed to make enemy detection of U.S. aircraft difficult. These complex profiles require additional personnel to perform the various tasks to accomplish the mission effectively (10:1-6).

Air Force aircraft should have the capability to perform effectively in a variety of unusual circumstances and various combat conditions. These conditions will place heavy demands on the aircraft and aircrews due to the high workloads placed on the aircrews during combat and the unpredictability of events associated with combat missions. It is essential that Air Force leaders and decision makers understand the advantages and disadvantages of replacing a Nav/WSO/EWO with technological systems.

The trend to replace the Nav/WSO/EWO in U.S. Air Force aircraft in order to reduce operational cost is clearly visible. However, an Air Force Institute of Technology (AFIT) thesis written by Major James T Denney found that many Air Force pilots are not convinced replacing the Nav/WSO/EWO is the optimum approach. They indicated reservations about their ability to perform certain missions without a Nav/WSO/EWO. Their responses indicated a disagreement with the current trend to replace the Nav/WSO/EWO (15:116-118). An F-111 Fighter Weapons School instructor, a captain with 2000 total flying hours, stated that "I feel advanced navigation systems enhance the role of the WSO. In the night low level environment a WSO is critical due to the task-saturating nature of the mission" (15:117).

Furthermore, an F-15E pilot, a major with 2600 total flying hours and 315 hours in the F-4, stated that "The F-15E mission (night low level weapons delivery) requires a well trained WSO to accomplish the task" (15:121).

Finally, an F-16C Block 40 Electronic Combat pilot, a captain with 790 total flying hours, had this to say:

> With the LANTIRN system becoming operational, the need for increased attention to safety of flight dictates the need for a WSO. Low altitude night navigation and target ID is inherently difficult and when you factor in the threat arrays that we are forced to penetrate in wartime, the mission success will be very difficult to achieve. You cannot expect a pilot to have his eyes outside the cockpit 100% of the time. There are too many other duties: radar se rch, inflight navigation, systems updates, weapons operations, etc. We have gone from a VFR lightweight air-to-air weapons system to a more aerodynamic F-4. (15:162)

Despite current trends to replace the Nav/WSO/EWO in combat aircraft, these comments from pilots flying combat aircraft indicate it may not be a wise decision. This research effort will attempt to investigate the issues surrounding the replacement of the Nav/WSO/EWO on combat aircraft with advanced cockpit automation technologies.

Statement of Problem

It is difficult to accurately determine the impact on mission effectiveness during combat missions when replacing the Nav/WSO/EWO with new cockpit automation technologies. In an effort to investigate some of the issues involved with the problem, the researchers have posed the following research question.

Research Question

The overall question this research will address is: Do pilots believe the Nav/WSO/EWO can effectively be replaced by new cockpit automation technologies on aircraft performing missions in high threat combat environments?

Research Objective

The primary objective of this study is to gather sufficient data from six different Air Force pilot groups to assess whether the Nav/WSO/EWO can effectively be replaced by cockpit automation technologies on various combat aircraft.

To answer the research question, the following specific questions and hypotheses will be investigated.

Investigative Questions and Hypotheses

1. What do the pilots of a particular aircraft type believe are the critical mission effectiveness factors for the mission they perform?

Hypothesis #1: Each aircraft type will possess different critical mission effectiveness factors for the combat missions they perform.

2. Do the pilots of a particular aircraft type believe a Nav/WSO/EWO would enhance the performance of their aircraft concerning critical mission effectiveness factors for the mission it performs?

Hypothesis #2: A Nav/WSO/EWO is necessary to enhance critical mission effectiveness factors on combat missions.

3. Does the perception of the need for a Nav/WSO/EWO depend on the type of mission flown?

Hypothesis #3: The perceived need for a Nav/WSO/EWO is based on the type of mission flown.

4. Does the perception of the need for a Nav/WSO/EWO depend on the experience level of the pilot?

Hypothesis #4: More experienced pilots will recognize the benefits of a Nav/WSO/EWO in helping to effectively perform the mission they fly.

Scope of Study

This study examines the impact of the Nav/WSO/EWO on combat mission effectiveness. A survey was administered to Air Force pilots to determine if they believed: 1) the Nav/WSO/EWO could be effectively replaced by advanced cockpit technology, and 2) the requirement for a Nav/WSO/EWO would change depending on the type of mission or selected critical elements of mission effectiveness. Nav/WSO/EWOs were not surveyed because, as those most directly affected by recent changes, they could be expected to argue in favor of maintaining the Nav/WSO/EWO position. The pilot, however, is the aircrew member who will be asked to perform additional tasks if crew strength is reduced. In addition, to compare the results of the survey and draw consistent conclusions, only pilots were asked to participate because some of the aircraft of interest do not incorporate Nav/WSO/EWO's. Finally, statistical rigor demands the population under study be limited to draw accurate conclusions. Pilots were surveyed in MAC, SAC, and the tactical air forces (TAF). The study attempted to obtain responses from pilots in the following aircraft: B-52, KC-135, C-130, F-15E, F-16, and A-10. The survey was sent to a randomly selected sample of pilots for each aircraft. No attempt was made to target only those pilots having actual combat experience. The researchers hoped to obtain responses from pilots who had combat experience and from those who did not, so that comparisons could be made based on experience levels. The responses were compared to examine differences in perceptions among pilots of different aircraft types concerning the necessity for a Nav/WSO/EWO in the cockpit.

Assumptions

This study assumes that the aircrew members selected to participate in the survey constitute a representative sample of the overall population of interest. Further, it is assumed that these individuals freely participated in this survey and gave honest answers to the questions posed.

Conclusion

This chapter has tried to identify the various issues surrounding the trend in the U.S. Air Force to replace the navigator/weapon systems officer/electronic warfare officer with new cockpit automation technologies in combat aircraft. Even though the trend is clearly visible, there are those who argue that allowing advanced cockpit technologies to replace the Nav/WSO/EWO due to economic factors is not the optimum decision. Over-reliance on technology to the point of reducing the size of the aircrew may adversely effect the combat mission effectiveness of some combat aircraft. This chapter also introduced the research and investigative questions as well as the scope of the study and assumptions of this research. Chapter II will discuss previous studies and research found in the literature addressing the impact of aircrew size on combat mission effectiveness.

II. LITERATURE REVIEW

Chapter Overview

This chapter contains a search of written material and interviews with individuals who participated in or witnessed the decisions that incorporated advanced cockpit technologies in Air Force combat aircraft. The literature review summarizes the authors' attempt to search available sources to help answer the research question raised in chapter one. The objectives of this portion of the thesis are to look at: 1) USAF attempts to incorporate advanced cockpit technologies into operational aircraft, including Air Force sponsored or contractor initiated studies; 2) the criteria these studies found to be critical to combat mission effectiveness; 3) the decisions Air Force leadership made after receiving these studies; and finally, 4) results, if available to this research team, of the Air Force's decisions concerning technology incorporation and the reduction of aircrew members.

The review of existing literature and interviews is organized by aircraft type. Sections of this review are segregated in the following manner: air-to-air refueling aircraft (KC-135 Stratotanker and KC-10 Extender), tactical fighter aircraft (F-15E Strike Eagle, F-16 and F-16R Fighting Falcon, and F/A-18 Hornet), airlift aircraft (C-130

Hercules and C-17), strategic bomber aircraft (B-52 Stratofortress, B-1 Lancer, and B-2), and tactical attack aircraft (A-10 Thunderbolt II). The decision to organize this chapter by aircraft types results from the diverse missions each type of aircraft performs and each major command's (MAJCOM's) commitment to incorporate advanced cockpit technologies in its aircraft. The assumption is that combat mission effectiveness criteria will differ according to aircraft type. Stratifying the mission effectiveness criteria by aircraft type also enables the authors to examine the decision-making process of each MAJCOM in its efforts to apply today's technology in Air Force combat aircraft.

Finally, a summary section of the literature review presents the findings of the works examined in this literature search. The findings presented in this chapter determine the direction of this team's research effort and mode of research.

Strategic Air-to-Air Refueling Aircraft

Strategic Air Command (SAC) has, since 1975, been searching for a mechanism to replace the navigator on its KC-135 air refueling aircraft (13:iii). Air Force Magazine, in its "1991 USAF Almanac," gives an excellent description of the KC-135's role in SAC:

> As single manager of all USAF KC-135 tanker aircraft, SAC supports its own refueling requirements as well as the aerial refueling

> requirements of other Air Force commands, the US Navy and Marines, and other nations. In particular, the KC-135 is an integral part of the Single Integrated Operational Plan (SIOP), providing mission-critical fuel to the strategic bomber force, a role that proved crucial in the war in the Persian Gulf.... First flight of the KC-135A was in August 1956 and by 1966 a total of 732 had been built. Many of the 633 remaining in operational service have been modified to later standards in three programs initiated to enhance the KC-135's capability and extend its operational utility well into the next century. (44:173)

Many studies sponsored by SAC have examined ways in which the navigator position might be eliminated from the KC-135 Stratotanker. The first attempt at replacing the navigator was documented in a study entitled GIANT CHANCE. The hypothesis explored in this study was to transform the copilot position into a copilot/navigator position, thus permitting SAC to eliminate the navigator. The results of the GIANT CHANCE study were not encouraging:

> This study [GIANT CHANCE] indicated that omitting the navigator and giving the navigation function to the copilot resulted in excessively high workloads on the copilot that jeopardized the mission and, in some cases, constituted a safety hazard. (11:1)

A second study, GIANT BOOM, looked at the possibility of replacing the navigator on the KC-135 with a second enlisted boom operator, designated a Flight Systems Operator (FSO). The FSO, an assumed less costly alternative to a navigator, would be trained in the basics of aircraft navigation (11:1). This idea was abandoned after the amount and cost of training and pre-implementation testing required were examined in detail (11:21).

A third study, performed in 1976, again examined the three man crew on board the KC-135. This study incorporated actual test flights to gain test data using 1976 state-of-the-art avionics (12:1). "Results of this test program definitely indicate that task overloads on the copilot, and in some cases the pilot, are going to occur when using a three man crew" (12:21).

From June 1978 to May 1979, a fourth study was performed, again examining the three man KC-135 crew complement. In an aircraft performing only the primary mission of aerial refueling (no additional alert commitment taskings), the results were encouraging:

> Based on the results of this study, it can be stated that accomplishment of the aerial refueling mission is feasible with a two pilot, one boom operator flight crew by reallocating crew tasks and by utilizing 1980 state-of-the-art crew systems. (21:xiii)

Currently, SAC is attempting to find a workable approach to eliminating the KC-135 navigator position. Headquarters, US Air Force (HQ USAF) suggested that the Commander-in-Chief, Strategic Air Command (CINCSAC), "in concert with AFLC [Air Force Logistics Command] and AFSC [Air Force Systems Command], pursue similar initiatives [economize by reducing aircrew complement] for the KC-135 force" (27:1).

A May 1990 Headquarters SAC (HQ SAC/DONK) staff summary sheet and its accompanying tabs gives many insights into the critical issues facing SAC decision makers. The areas of concern that prevent SAC leadership from purchasing advanced cockpit technologies to eliminate the KC-135 navigator position are the estimated costs and payback period of aircraft modification, required Stratotanker combat capabilities, and aircraft safety (3:2; 41:1-2; 5:1).

Utilizing normal acquisition processes, the cost of modifying the entire KC-135 fleet with advanced cockpit technologies is approximately $821 million (FY 1989 dollars) (3:2). According to HQ SAC, these modifications would not pay for themselves in personnel savings until the new equipment had been in the KC-135 fleet for 25 years (3:2). The "break-even" economic point for this extensive cockpit modification would occur when the average age of the Stratotanker fleet is 65 years (3:3).

Several directorates in HQ SAC warn of replacing the KC-135 navigator because the Stratotanker might not be able to perform its current mission. An April 6, 1990, letter from the Strategic Air Command's Director of Bomber Operations (HQ SAC/DOO) voiced his concerns:

> Combat capability. The KC-135 crew composition is based on contingency and EWO [Emergency War Order] wartime requirements. The navigator adds mission responsiveness and flexibility advanced avionics can not match. Below are several areas which improved avionics may not cope with effectively:
>
> (a) Electro Magnetic Pulse Damage
> (b) Overwater ferry missions
> (c) EMCON missions
> (d) Aircraft equipment malfunctions
> (e) Multiple fighter rendezvous
> (f) Hazardous weather avoidance
> (g) Rapid mission changes, including movement of the refueling airspace

(h) Assistance during aircraft emergencies (37:1)

In summary, HQ SAC/DOO sees the KC-135 as being less mission capable with advanced avionics; degradation of many aircraft subsystems that presently do not inhibit the Stratotanker's ability to go to war would now become critical as Emergency War Order (EWO) "Go" or "No Go" items (37:2). The result of more critical aircraft subsystems is a less mission-effective aircraft.

Concerns are also expressed by SAC's Director of Bomber Operations over KC-135 aircraft safety if new avionics are incorporated to replace the navigator:

> The KC-135 pilot team is on the verge of task saturation during weather avoidance, rendezvous, multiple tanker refuelings, and navigation through busy air traffic control areas. Adding key navigator responsibilities to the pilot team during these critical phases of flight would create an unsafe task saturated environment, where a minor problem could distract both pilots and cause a major aircraft accident. (37:1)

Despite the pressures from Air Force leadership, SAC has yet to find the workable solution that balances economic savings with the demands of the Stratotanker's mission. Flight safety also plays an important role in SAC's decision to replace the navigator with state-of-the-art avionics. The concerns that have prevented SAC from eliminating the navigator from the KC-135 fleet have affected the USAF's latest tanker--the KC-10 Extender.

In 1976, SAC commissioned a study of what would be the minimum crew complement of the replacement for the KC-135, the Advanced Tanker/Cargo Aircraft (ATCA) (13:iv). One of SAC's major objectives in procuring the ATCA was to use off-the-shelf technology and convert a Boeing 747 or McDonnell Douglas DC-10 while minimizing overall aircraft costs (13:1). The findings of this 1976 ATCA study recommended a four man crew:

> (1) The four-man ATCA crew consisting of pilot, copilot, navigator/flight engineer, and boom operator is most advantageous in that it is the minimum crew composition which can handle most required crew tasks below 100 percent task loading under all operational conditions. This crew composition affords maximum flexibility for mission change and EWO [Emergency War Order] activities. It also requires the least amount of training required to operate the avionics/navigation systems.
> (2) The three-man ATCA crew shows an overload situation in most departures from a standard air refueling mission profile and would appear to generate an unacceptably high workload in the EWO environment. However, further empirical studies under actual or near actual conditions are required to definitely establish the feasibility of a three man ATCA crew composition. (13:29)

Eventually, the KC-10 aircraft was fielded with a three man crew. The Air Force Magazine's "1991 USAF Almanac" explains the Extender is more capable than the KC-135 Stratotanker in many aspects of the air-to-air refueling/cargo carrying mission, but omits any mention of the KC-10's integration into the SIOP.

> The KC-10 was conceived to meet USAF requirements for an Advanced Tanker/Cargo Aircraft (ATCA). It is based on the commercial DC-10 Series 30CF, modified to included fuselage fuel cells, a boom operator's station with aerial refueling boom and integral hose reel/drogue unit, a receiver refueling receptacle, and military avionics. In its primary role of enhancing worldwide air mobility, the KC-10A combines the tasks of tanker

and cargo aircraft in a single unit.... The KC-10A made its maiden flight in July 1980 and the first service usage by SAC took place in March 1981.... Fifty-nine KC-10As are in the USAF inventory. (44:173)

The Stratotanker and Extender demonstrate the inability of current advanced cockpit technologies to completely replace the navigator. Advanced technologies permit an aircrew complement to be reduced on Air Force air-to-air refueling aircraft if the mission is well planned, if the aircraft is limited to missions the advanced avionics were designed to accomplish, and if the mission does not include unplanned contingencies such as Emergency War Order actions, complex mission changes, and emergencies. Once these limitations of advanced avionics are overcome, SAC will probably not hesitate to eliminate the navigator from all air-to-air refueling aircraft.

Unless a major breakthrough in cockpit avionics technologies occur, one can conclude the KC-10 Extender will not replace the KC-135. The original intent was to use the technologically superior Extender not only to replace the Stratotanker, but to add an important cargo carrying feature the Stratotanker does not possess. SAC's serious reservations concerning the Extender's versatility to function in the ever- changing and extremely demanding EWO environment, and the lack of hardened critical navigation equipment against electro magnetic pulse (EMP) prevents the KC-10 from replacing the Stratotanker (37:1; 5:1). In its current configuration, the KC-10 can be seen as a unique supplement to the KC-135 in the air-to-air refueling role and as a highly versatile system in the combined air-to-air refueling/cargo carrying mission.

Tactical Fighter Aircraft

For years the tactical fighter community has argued over the issue of two-seat versus single-seat fighters. Mr. Eric Crawford, an engineer assigned to the Advanced Tactical Fighter (ATF) System Program Office (SPO) at Wright-Patterson AFB, Ohio, summed up the argument between single seat and two-seat fighters in his report entitled, "One Versus Two Seat Fighter Aircraft": "The small number of studies on 1 vs 2 man cockpits suggests that the suggestion to develop a 1 or 2 seat aircraft has historically been based primarily on economic and political factors" (10:1). The F-15E Strike Eagle and the F-16 Fighting Falcon acquisition and operational histories support Crawford's assertions of economic and political pressures influencing the crew complement of fighter aircraft.

Multi-role aircraft can be defined as aircraft that perform more than one mission. The F-15E and F-16 perform air-to-air (A/A) and air-to-ground (A/G) missions.

Mission requirements of the F-15E Strike Eagle and the means to achieve these requirements were developed early in the aircraft's developmental life. The following quote states the Tactical Air Forces' (TAF) need for a Dual Role Fighter (DRF):

> The Tactical Air Command (TAC) validated a Statement of Operational Need for a dual role fighter (DRF). This weapon system is to be a replacement for the F-4D and is to exhibit increased range and payload capabilities in both the air-to-air (A/A) and air-to-ground (A/G) arenas (hence the "dual role" descriptor). A derivative version of either the F-15 or F-16.... is to provide the airframe. (32:630-631)

To accomplish the TAC missions, a two man crew with sophisticated avionics was needed in the DRF (F-15E) (32:630). Mission complexities and the difficulty of employing various avionics and weapon delivery systems were identified early as problems that had to be overcome.

> The DRF crew will have to overcome the high level of complexity inherent in applying a suite of advanced technologies under conditions of high threat, adverse weather, and darkness in carrying missions which may combine both A/A and A/G tasking. (32:631)

The decision to use a dual seat cockpit for the DRF was supported by Crawford's findings when he outlined the advantages of a two-seat cockpit:

1. All-weather capability.
2. More survivable against all threats.
3. Operable in degraded modes.
4. Superior low level flight/attack.
5. Superior target acquisition in low and medium threat environments.
6. Increased outside cockpit surveillance.
7. Decreased pilot workload.
8. Increased flight control due to decreased workload.
9. More efficient fuel management.
10. Increased pilot training opportunities through training transfer when WSO advances to the front seat.
11. Increased opportunity to provide and maintain flying-duty assignments for more of the USAF rated officer personnel.
12. Prevent some human errors. (10:8)

Roik L Hockenberger, of Hughes Aircraft Company, in his paper, "Aircrew Performance with Simulated Advanced Radar and FLIR Sensors in Single- and Two-Place Crew Stations," also supports many of Crawford's contentions concerning two seat aircraft advantages: "For example, performance scores revealed an average 15 percent improvement for the two place crew, with an average 20 percent reduction in subjective workload rating" (28:168).

From this information, one would infer that for a multi-role aircraft, the two-seat aircrew complement with the latest technology is the optimum configuration. A two place fighter crew complement also suggests the highest probability of mission effectiveness.

The DRF became the F-15E. The Strike Eagle incorporates much of the latest in fighter technology.

> The F-15E is USAF's two-seat, dual-role, totally integrated fighter for all-weather air-to-air and deep interdiction missions.... For low-altitude, high speed penetration and precision attack on tactical targets at night and in adverse weather, the F-15E carries a high resolution Hughes APG-70 radar and LANTIRN (Low-Altitude Navigation and Targeting Infrared for Night) pods, with wide-field forward-looking infrared (FLIR).... Funding for 200 F-15Es has been approved, with the final buy in FY 1991. (44:165)

The General Dynamics F-16 Fighting Falcon, the Air Force's most numerous multi-role fighter, is a single seat aircraft. Since its introduction into the active inventory in 1979, the USAF F-16 fleet has been in an almost constant state of upgrade, modification, and change:

> A forward-looking plan for the aircraft, known as the Multinational Staged Improvement Program (MSIP), was implemented by USAF in February 1980 to ensure the aircraft's ability to accept systems under development, thereby minimizing retrofit costs. As a first stage, all F-16s delivered since November 1981 have had built-in structural and wiring provisions and systems architecture that expand the single-seater's multi-role flexibility. MSIP II was applicable to the improved F-16C.... These aircraft have a Westinghouse APG-68 multimode radar, with increased range and advanced ECCM [Electronic Counter Counter Measures],.... Also introduced were systems improvements that include installation of a LANTIRN nav/attack system, GPS [Global Positioning System],...The F-16 program involves the US Navy, as well as 15 foreign nations, more than 50 distinct aircraft configurations, and extensive foreign coproduction. (44:165)

The F-16 Fighting Falcon currently performs a myriad of missions for the Air Force. These include enemy defense suppression (WILD WEASEL); air defense; night, adverse weather ground attack; day ground attack; non-conventional strike operations; and maritime attack operations (44:165).

As Crawford points out, distinct advantages are associated with single seat aircraft like the F-16:

1. Lower cost.
2. Reduced weight.
3. Superior target acquisition in high threat environment (sacrifice threat avoidance to achieve this).
4. Decreased life cycle cost.
5. No crew coordination problems.
6. Use less fuel and can carry more fuel.
7. Automatic radar detection provides superior target acquisition for detected threats.
8. Superior aircraft performance in acceleration and range. (10:8)

The Strike Eagle and Fighting Falcon do not have identical mission taskings, but the aircrew of each aircraft will have to perform many of the same tasks to perform their respective missions. For example, they both carry the LANTIRN navigation/attack system. This system permits both aircraft to perform assigned ground attack taskings during nighttime, in adverse weather. The noticeable difference in the two aircraft is that the F-15E possesses a team of two aviators to operate and use the LANTIRN system to achieve its combat objectives, while the F-16 utilizes the skill of one pilot to perform the same functions. Crawford and Hockenberger stress the need for two aircrew members to perform the nighttime, adverse weather mission. Air Force decisions in equipping the Fighting Falcon obviously disagree with Crawford and Hockenberger--why? The answer may lie in developmental decisions of these two aircraft. The F-16, originally designed to be a high performance, day only, clear weather limited dual role fighter, is now a technological marvel. The Fighting Falcon is now an all weather, day or night, dual role fighter. Over the past twelve years, the Air Force has added proven technologies to increase the F-16's combat capability. The F-16 pilot now has all of the tools to perform almost any Air Force tactical fighter mission (44:165).

The Fighting Falcon has also become the free world's premier fighter. As stated earlier, 15 US allies fly some version of the F-16. The export of this fighter has not only generated tremendous revenues for General Dynamics and F-16 subcontractors, but it is also an important foreign policy tool. The F-16 seems to support Crawford's assertion that politics can play an important role in the decisions of aircraft and aircrew configuration. The F-16 is the jet that appeals all potential free world fighter customers.

The F-15E has had the benefit of a short, stable operational life. The Strike Eagle, in contrast to the F-16, performs the mission it was initially designed to perform. No new technologies have been added to change or modify the mission of this dual role fighter.

The United States is the only country using the F-15E. The Strike Eagle has been exempted from many of the political pressures the F-16 experienced. The designers and McDonnell-Douglas had only one customer to please--the US Air Force.

This examination of the F-15E and F-16 leads one to believe the Air Force's primary single-seat aircraft, the F-16, can perform many of the same tasks equally as well as its primary two-seat fighter, the F-15E. The only actual "test" of these two aircraft has been the recent Persian Gulf conflict. Much of the combat operations data from DESERT STORM is still classified and not available for this review. However, a June 1991 Air Force Magazine interview with Lieutenant General Charles A Horner, Central Air Forces commander, gives a hint as to the effectiveness of these two aircraft in DESERT STORM:

> The A-10s and the F-16s did a lot of work that was not really heralded. They basically kept pressure on Saddam during the daytime.... The [F]-117, the

> [F]-111, and the F-15E and, to some extent, the F-16 LANTIRN aircraft all did much the same work. They were most useful against hard-point targets, bunkers, aircraft shelters, bridges, the things you saw on television.... They were very efficient. (33:60)

This short statement does not give a detailed critique of each aircraft's contribution to the war effort, but it does hint the LANTIRN-equipped F-16 did not perform on the same level as the LANTIRN-equipped F-15E. This contrast between the two aircrafts' performances, once again, highlights the unsettled argument over the capabilities of the single-seat and two-seat tactical fighter aircraft.

From this discussion, one begins to question the ability of the single-seat pilot to <u>effectively</u> use all of the advanced technologies at his disposal. No Air Force studies could be located that addressed F-16 pilot task saturation. However, the US Navy has performed research related to F/A-18 Hornet pilot task saturation, and General Dynamics studied the possibility of a tactical reconnaissance version of the F-16 (the F-16R).

In 1985, the United States Navy (USN) tasked the Center for Naval Analyses (CNA) to examine the issue of single seat as opposed to dual seats with regard to their use in F/A-18 Hornets (8:1).

> Analysts performed an extensive literature search on the subject, but the search was not conclusive. The penalty for an additional crewman in the cockpit (e.g., reduced fuel capacity, increased carrier-habitability problems, and costs) could be quantified. The benefits provided by the presence of a second crewman, however, could not be so easily quantified. The naval mission identified

> as the one most likely to benefit from the presence of an additional crewman was the Land Strike mission. The dual-seat F/A-18 was expecte to be more survivable and to have a higher weapon-delivery effectiveness in Land Strikes. (8:1)

CNA opted to use a simulator to test the hypotheses of the dual-seat F/A-18 advantages. "The simulation took place at the Manned Air Combat Simulator (MACS III) facility operated by McDonnell Aircraft Company (MCAIR) in St. Louis, Missouri" (8:1).

CNA found trends supporting the hypothesis that certain missions (escort and close air support) are better executed by single-seat crews (8:26). Crawford's report also stated CAS and escort missions were best accomplished by a one man fighter (10:2). In contrast, two-seat crews performed day strike missions more effectively than did single-seat crews (8:26-27). Overall, two-seat crews performed <u>all</u> missions more effectively and had a significantly higher chance of surviving a combat mission at all threat levels than did single-seat crews (8:26-27). The trends highlighted here are obtained from the only unclassified data available from the thirty-plus volumes of the Navy's F/A-18 study.

The F/A-18 study provides some possible answers to the differences in F-15E and F-16 combat performances in DESERT STORM. The CNA study points out that in most circumstances a two-seat tactical fighter crew is more combat effective than one fighter pilot in a technologically advanced aircraft. The classification of this study prevented the research team from examining any specific combat effectiveness factors CNA may have discovered.

Another study that supports the overall findings of the F/A-18 study is General Dynamics' exploration of an F-16R. General Dynamics was asked by the USAF to study the concept of a tactical reconnaissance version of the F-16. General Dynamics built single seat and two seat simulators to examine the feasibility of an F-16R. One result of this study was a recommendation for a two seat configuration for a high threat environment (23:Executive Summary). Inexperienced, experienced, and highly experienced pilots and WSOs from F-16 and RF-4C aircraft made up the test subjects (23:3). Of interest in this study was F-16 pilot reaction to the incorporation of a WSO into the Fighting Falcon: "The pilots were asked to indicate their perception of how much the WSO contributed to the overall success of the mission [mission effectiveness]. Nine of the ten pilots rated the WSO's contribution as being "of significant value or better" (23:43). Currently, a significant portion of the tactical reconnaissance mission is flown at night. This mission requires low level flight by radar and the ability to avoid threats and find the target. The findings of the General Dynamics simulation agree with Crawford's advantages of a two seat fighter: all-weather capability, more survivable, and superior low level flight.

The TAF faces the same pressure as the Strategic Air Command (SAC) to economize. This desire to control costs can affect the TAF's decision as to buy a single-seat or two-seat fighter. The CNA study, performed for the Navy, presented the personnel costs of an additional crew member. One can assume the cost of a Naval Flight Officer (NFO) will be roughly equivalent to the cost of a WSO or EWO.

Each Naval Flight Officer (NFO) required for the two-seat F/A-18 would have a one time acquisition and training cost of $600 thousand (1985 dollars) and an annual recurring cost of $90.2 thousand (1985 dollars) (7:8). The NFO personnel cost for a mix of one dual-seat F/A-18 for every three single-seat F/A-18s is $669 million (1985 dollars) over the operational life of the aircraft (7:9). These figures make it clear why economics can play a decisive role in deciding whether to design a single or dual-seat fighter.

The high cost of personnel and F-16 airframe modification to incorporate a second seat may have forced the Air Force not to adopt General Dynamics' recommendation for an F-16R. Recently, the Air Force announced plans to purchase a reconnaissance pod that can be fitted to a modified F-16 (1:27). This decision places the LANTIRN-equipped F-16 reconnaissance pilot in the same position as the LANTIRN-equipped F-16 attack pilot; the pilot may be unable to fully exploit the capabilities of his aircraft in a combat situation.

In summarizing the tactical fighter portion of this literature review, the authors find the TAF's decisions concerning incorporation of advanced cockpit technologies in conflict with many studies. For example, the studies reviewed here show most tactical fighter missions are best performed by two-seat aircraft. Advanced cockpit technologies, according to these studies, increase the mission effectiveness of each crew member. The Air Force appears to use these new technologies to eliminate crew members, thus reducing the combat mission effectiveness it has worked so hard to increase through advanced technologies.

The issue of pilot task saturation also appears to take a backseat to cutting Air Force expenses. The USAF has spared little expense in modifying the F-16 into an all-weather dual role fighter without investigating whether or not the pilot can cope with the increased workload. Early indications from DESERT STORM are that the Fighting Falcon did not enjoy the same level of success as the F-15E in night bombing operations.

Finally, no mission effectiveness factors could be gleaned from any Air Force sources. Some contractor and US Navy sponsored studies identified certain missions or types of missions that were best flown by a certain crew complement. These studies, however, did not give the factors that determined why a specified crew complement was preferred.

Transport Aircraft

Military Airlift Command (MAC) asked Air Force Systems Command (AFSC) to examine the possibilities of incorporating advanced cockpit technologies into the C-130H tactical transport aircraft. AFSC asked Lockheed Aeronautical Systems Company to write several trade studies concerning advanced technology incorporation into the C-130H flight deck.

The Lockheed C-130 Hercules has provided excellent service to the Air Force for more than 35 years. Air Force Magazine provides a short history of the Hercules:

> In times of crisis, as well as peace, the remarkable C-130 Hercules continues to demonstrate its wide operational capabilities. Basic and specialized versions perform a diversity of roles worldwide, including airlift support, DEW [Distant Early Warning] Line and Arctic ice cap resupply, aeromedical missions, natural disaster relief missions, aerial spray missions, and fire-fighting duties for the US Forest Service. It is now four decades since TAC [Tactical Air Command] issued its original design specification, yet the aircraft remains in production. The initial model was the C-130A, first flown in April 1955,.... The C-130B introduced 4,050 ehp Allison T56-A-7 turboprops; the first of 134 entered USAF service in April 1959..... Twelve C-130Ds were modified C-130As for use in the arctic,.... The C-130E is an extended-range development of the C-130B, with large underwing fuel tanks; 389 were ordered for MAC and TAC, with deliveries beginning in April 1962.... Generally similar to the E model, the basic C-130H has upgraded T-56-A-15 turboprops, a redesigned outer wing, updated avionics, and other, minor improvements; delivery began in April 1975. Well over 350 C-130Hs and derivatives have been ordered for the US services. (44:172)

Since the inception of the C-130A, the flight station's original controls and displays have changed little (40:3).

There have also been no changes in the C-130's crew complement: a pilot, a copilot, a navigator, a flight engineer, and loadmaster (40:3).

Lockheed's trade study and AFSC refer to the proposed cockpit enhanced C-130H as the C-130J. The motivation for MAC to look into these extensive aircraft modifications was primarily economic savings.

> The purpose of this study was to determine if a modernized flight station for the C-130"J" could reduce life-cycle costs through application of new crew systems technologies and reduction in the number of crew members. Clearly, lower operating costs can be achieved by reducing the number of maintenance man-hours required and the cockpit crew members from four to two [elimination of the navigator and flight engineer]. (40:1)

Lockheed has presented the Air Force three alternatives for the C-130J configuration:

> Alternative 1, which incorporates the fewest changes from the baseline C-130H, maintains the same flight crew composition but the electro mechanical instruments on the main instrument panel are replaced by six flat panel, color, liquid crystal displays (LCD). One LCD at the navigator's station replaces the radar scope.
>
> Alternative 2 reduces the flight crew size by eliminating the flight engineer and navigator whose functions are replaced primarily by system automation and state-of-the-art avionics. It also features six head-down LCDs.
>
> Alternative 3 is identical to Alternative 2 except that two LCDs on the main instrument panel are replaced by two head-up displays (HUD). (40:ii)

In evaluating the three alternatives, Lockheed made seven assumptions:

> (1) High resolution color liquid crystal display technology will be mature enough for the production display system. If not, distributed cathode ray tubes (flat CRTs) will be available.

(2) Costs associated with changes to aircraft functional systems, except those related to other trade studies [authored by Lockheed] will be charged to the flight station.

(3) Avionics architecture will provide adequate capability and flexibility to accommodate two-pilot crew system needs.

(4) When an avionics trade study for a system exists, the cost of that system, including the displays and controls, will be accounted for by that trade study.

(5) Controls and displays for defensive systems, if installed, will be designed so that they can be operated by the two-pilot crew.

(6) Only space provisions are included for aerial refueling. If system is installed, controls and displays will be designed so that they can be operated by the two-pilot crew.

(7) The impact of operating in a contaminated nuclear, biological or chemical environment or where laser weapons are a threat must be assessed in a future study. (40:10-11)

Lockheed examined several important areas in its analysis prior to recommending one of the alternatives to MAC. Some of the areas examined included survivability/vulnerability, supportability, life cycle cost, risk, growth capability implications, and operational capability implications.

"Alternative 1 will not result in any change to the aircraft vulnerable area" (40:13). Overall survivability may increase slightly in alternative 1 (40:13). "Alternatives 2 and 3 will result in a small reduction (<1 sq ft) in the aircraft's vulnerable area" (40:13). There may also be a slight increase in overall survivability due to the reduced cockpit task loading (40:13).

In the area of supportability, Alternative 2 provides the best supportability potential (40:13). Alternative 1 achieves its increased supportability from the replacement of less reliable analog instruments and other navigation systems (40:14). "Alternative 1 configuration is the least desirable due to its retention of the majority of the four-crew provisions" (40:14).

The elimination of the navigator and flight engineer and their workstations make Alternative 2 much more supportable than Alternative 1 (40:14). Alternative 2 appears superior to alternative 3 because of the increased requirements for maintenance training, training facilities, support equipment, software support requirements, and decreased commonality of spares, attributed to the head-up displays (HUDs) (40:15).

The Lockheed trade study discussion of life cycle costs pointed out the high cost of personnel compared to systems.

> Of primary interest is the question of a two- versus four-person flight crew, while of secondary interest is the cost impact of the head-up display. Three conclusions are apparent: first, each of the proposed flight stations adds acquisition cost to the baseline C-130. Second, however, the two-person flight stations result in <u>dramatic</u> life cycle cost savings, due to the reduction in manpower costs. Finally, the head-up display adds both acquisition and total life cycle cost. The net 30-year life cycle cost change from the baseline C-130 is a $526,000 increase for alternative 1 and a $7,093,000 and $6,862,000 savings for Alternatives 2 and 3, respectively. These costs are per aircraft, expressed in 1989 dollars. (40:15)

The overall risk assessment for alternative 1 is low, and for Alternatives 2 and 3, the risk is rated as moderate (40:Summary). The definitions for low, moderate, and high risks are given here:

> Low Risk--Minimal state-of-the-art extension; similar to past designs; several feasible approaches defined; program required; activity is ongoing.
>
> Moderate Risk--Moderate state-of-the-art extension; moderate to significant extension from past designs; limited number of design options available; moderate in cost and noncontroversial.
>
> High Risk--Significant development required to extend the state-of-the-art; significant extension from past designs; only one or two design options available; moderate to high cost and potentially controversial. (40:17)

Because they are still in development, liquid crystal displays are the only items that possess a rating of high risk (40:17).

The following comments were made concerning the C-130J growth capability implications:

> Alternative 1 has a great deal of flexibility and expandability in both displays and controls.... Thus, new systems could potentially be added to the airplane without a sizeable change in control or display hardware, while maintaining an integrated crew system design.
>
> For Alternatives 2 and 3, a major philosophy in the design of the flight station has been to miniaturize controls so that they can all be reachable by two pilots and to automate functions whenever required. (40:21)

Lockheed's operational growth implications analysis for the C-130J emphasized the assertion that C-130 missions are becoming more demanding (40:23). This assertion is the main factor in the C-130J alternative growth implication analysis:

> Alternative 1 vastly improves the capability for displaying data to the pilots, and through integration of the weather radar and formation stationkeeping functions, it improves situational awareness and out-the-window view,.... The combinations of these changes to the flight station improves safety somewhat and provides a minor improvement in overall operational capability over the C-130H.
>
> Alternative 2 provides the same minor improvement in operational capability as Alternative 1.... The integration and automation of systems and the miniaturization of controls and displays are not intended to improve operational capability, but only make it possible to reduce the crew size.
>
> Alternative 3 provides moderately increased operational capability over the C-130H, somewhat more than Alternative 1 and 2.... The head-up display system permits the pilots to manually fly precise lateral and vertical flight profiles by displaying flight path data which is conformal to the pilots real-world view. This provides for much more accurate control in both IMC and VMC approach to landing, aerial delivery maneuvers including LAPES, and in cruise on low level routes.... Head-up guidance in the B727 has been certified for manual landings in Category IIIa weather conditions (zero ceiling, 700-ft runway visual range). The C-130 could achieve the same capability, which far exceeds its current ceiling and visibility restrictions. (40:23)

Lockheed recommended alternative 3 for the C-130J (40:30). The reasons cited by Lockheed for favoring alternative 3 are: meeting the Military Airlift Command (MAC) Statement of Need (SON), life cycle cost savings, and increased operational capability (40:30).

In summary, the financial savings aspect of producing a C-130 with the latest avionics and no navigator or flight engineer is attractive. From this study, however, the Air

Force would apparently be giving up some flexibility in C-130 two-person cockpit design. This flexibility loss is due to the requirement that all controls be accessible to the pilot and co-pilot. One must also suspect the projected savings Lockheed anticipates with the C-130J. The entire avionics update is based upon new and some unproven technologies. Any shortcomings or failures of these technologies or systems (for example, the liquid crystal displays) may drive the cost of the avionics package higher, thus eliminating some of the life cycle cost benefits. The Air Force has yet to build a simulator or buy an actual C-130J to perform tests to validate the Lockheed trade study. Any departure from the anticipated C-130J performance will force the USAF to spend more funds for research and development to correct any prototype shortcomings.

The C-130J advertises itself to be capable of performing any C-130A through C-130H mission. This claim echoes the same claim voiced by Strategic Air Command (SAC) when it hailed the KC-10 as the replacement for the KC-135. As previously described, the Stratotanker has yet to be replaced. If the C-130J is ever fielded, Military Airlift Command (MAC) may have to face the same types of mission capability shortcomings (too few aircrew members to cope with a demanding, ever-changing combat environment), decisions, and compromises SAC faced while operationally deploying the KC-10.

The C-130 is not the only aircraft Military Airlift Command (MAC) is looking to technology for improved operational capabilities and lower life cycle costs. The McDonnell Douglas C-17A is MAC's complement to the C-130 and successor to the C-141 fleets:

> The C-17A was developed to meet US force projection requirements. It is a heavy-lift, air-refuelable cargo transport, designed to provide intertheater and intratheater airlift of all classes of military cargo, including outsize. It will be able to operate routinely into small, austere airfields (3,000 ft x 90 ft) previously restricted to C-130s and will provide the first capability to airland or airdrop/extract outsize cargo in the tactical environment. The C-17A will not only enhance US airlift capability across the board but will also provide much needed force structure modernization.... with a total planned buy of 120.... with delivery commencing next year [1992] and IOC [initial operational capability] scheduled for FY 1994. (44:171)

The C-17A will possess a crew comprised of a pilot, a copilot, and a loadmaster (44:171).

From the inception of the C-17 program, MAC and McDonnell Douglas set out to develop an airplane that could perform all airlift missions without over-tasking the aircrew:

> An early objective of the C-17 design was to limit the flight deck to pilot and copilot. These could even be relatively young, low-time pilots who would be capable of performing all C-17 missions, single ship or in formation, with no special mission qualification training.... C-17 automation permits mission completion with low workload. The automatics are designed to take care of routine inside operations, thereby freeing the crew to spend their time on heads-up mission awareness. (35:98)

No trade studies or technical reports were available to explore how the C-17A plans to use technology to attain its anticipated performance levels. The same uncertainties that were previously mentioned concerning the C-130J also pertain to the C-17A.

Strategic Bomber Aircraft

In no other type of aircraft can the ability of modern cockpit technology to reduce the size of the crew be seen more clearly than in the B-52. The B-52, designed and developed in the 1950s, uses six crewmembers to accomplish its mission: two pilots, two navigators, an electronic warfare officer, and a gunner. In the early 1980's, the navigation systems were updated using current technology. The advanced navigation systems greatly improved the B-52's bombing and navigation accuracy. Improvements were so good that consideration was given to eliminating one of the navigators. Conducting a literature search, discussing the issue with Strategic Air Command Headquarters (HQ SAC) personnel, and interviewing a Boeing Military Airplane Company representative did not reveal any studies or reports which investigated the impact on combat effectiveness of moving from two navigators to one. The knowledge about the discussion of the idea to eliminate one of the navigators is based on one of the author's personal experience as a B-52 crewmember.

The B-1, designed and developed in the 1970s, incorporated much new automation technology, such that the crew complement was reduced to four to accomplish its mission: two pilots, one navigator (Nav), and one electronic warfare officer (EWO). Contact with the B-1 System Program Office (SPO) at Wright-Patterson AFB, an interview with a local Rockwell Company representative, and a search for any existing literature did not turn up any studies or reports which investigated B-1 crew combat effectiveness factors.

The B-2 incorporates the latest advances in cockpit automation technologies. The crew is composed of two pilots. Cockpit automation technology in conjunction with multiple system and component redundancy has eliminated the need for not only a navigator, but also the electronic warfare officer. The B-2 is being developed as a highly survivable strategic bomber to supplement, and ultimately replace, the B-1 in its penetration role (44:163). The B-2, due to advanced cockpit technology integration, will supposedly accomplish with two crewmembers what the B-52 now accomplishes with six. Contact with a representative of the B-2 SPO revealed that studies have been conducted which have evaluated a two man crew as opposed to a three man crew, but those studies were classified and could not be included in this research effort. The B-2 representative did state that the three man crew was found to be less efficient than a two man crew during periods of high workload due to crew coordination problems. He also stated that the lack of a

Nav/EWO position did not degrade the combat mission effectiveness of the airplane.

These comments do not parallel the findings concerning two seat fighter aircraft as opposed to single seat fighters. The possible differences in factors that make up combat mission effectiveness in tactical fighter missions and strategic bomber aircraft missions may dictate different guidelines in crew complement. Another reason for the reversal in crew complement findings in bombers and fighters may be that the bomber mission may be more receptive to advanced cockpit technologies replacing some aircrew functions.

Tactical Attack Aircraft

The A-10A Thunderbolt II is the Air Force's aircraft dedicated to providing close air support (CAS) to the US Army. It is a single-seat, single mission aircraft. The "1991 USAF Almanac" gives an overview of this unique aircraft:

> Designed specifically for the close air support (CAS) mission, the A-10A's ability to combine large military load, long loiter, and wide combat radius proved a vital asset to Operation DESERT STORM. In a typical antiarmor close air support mission, the A-10, affectionately nicknamed 'Warthog,' can fly 150 miles and remain on station for an hour. Equipment includes an inertial navigation system, head-up display, PAVE PENNY laser target identification pod, ECM [electronic counter measures], target penetration aids, self protection systems, and associated equipment for Maverick missiles and air-to-air missiles.

> Delivery of 713 A-10s was completed in March 1984. The first operational squadron was activated at Myrtle Beach AFB, S.C., in June 1977. (44:166)

The CAS mission is one of two missions Crawford and the Center for naval Analysis (CNA) agreed is better performed in a single seat aircraft (10:2; 8:26). However, these studies did not address the possibility of performing CAS at night or in adverse weather. As stated earlier, missions performed in bad weather or nighttime are best accomplished by a two-seat aircrew (10:8; 8:26-27). This argument, at first glance, would appear to have no bearing on the Air Force's decision to procure a single-seat A-10. However, the operational preferences of the A-10's beneficiary, the Army, is to conduct combat operations at night. US Army leadership has, since the 1970s, stated publicly its desire to perform its mission around the clock in any weather. Shortly after the A-10 became operational, Air Force leadership explored a night/adverse weather (N/AW) A-10:

> In 1978, Fairchild Republic leased back the first pre-production airframe to produce a prototype with night and adverse weather (N/AW) capabilities. The prototype was listed in Air Force inventories as the YA-10B, but it was known universally as the N/AW A-10.
>
> The second seat was raised, giving the weapon system operator clear forward visibility comparable to the pilot's.
>
> Electronics included an inertial navigation system and dual radar altimeters. Under the left wing, a ground mapping radar/moving target indicator was mounted. A forward-looking infrared (FLIR) system was podded under the fuselage. A low-light-level TV supplemented the FLIR for poor infrared conditions. The PAVE PENNY was retained, and some experimentation was done with a PAVE TACK laser designator.

> Everything worked, but the Air Force was not convinced of its need for the aircraft. Much of the testing went toward development of N/AW capabilities for a single-seat aircraft. Fairchild proposed a two-seat trainer, but the A-10 was simple enough that pilots didn't need two seat transition time. The A-10B never saw production; its prototype is still at Edwards. (2:30)

The description of the A-10A in the "1991 USAF Almanac," shows that none of the N/AW capabilities of the A-10B have been incorporated into the A-10A. These capabilities were necessary in Operation DESERT STORM.

A Cable News Network (CNN) story focused on an A-10A unit tasked with performing CAS at night. An interview with the unit's commander revealed the A-10A, in its present configuration, could accomplish night CAS only when there was no or little anti-aircraft artillery (AAA) threat. The squadron's pilots agreed upon an altitude they would not go below--an artificial floor. This "floor" was required because the A-10 pilots had no equipment to warn them of an impending ground impact. The pilots were able to see their targets by utilizing the infrared capability of their Maverick precision guided munition (PGM). The Maverick field-of-view is narrow, forcing the pilots to fly a very tight "S" shaped pattern over the target area to acquire targets. This tactic exposed the aircraft to ground threats. Once a target was acquired, the PGM was locked onto the target and launched. Upon launching the PGM, the A-10 pilot lost his night "eyes." The 30 millimeter gun internal to the A-10 was useless at night because the pilot could not see the target. Had there been a ʋiə ' · night AAA threat, night CAS would have been impossiLːe ˀck of air support might have impacted the US Arm, ⁄ to operate at night.

The A-10 is unusual in that Air Force leadership opted not to incorporate advanced technologies or additional aircrew members to increase combat capabiːity. Despite the Army's doctrine of night combat operations, Air Force leaders saw no need for N/AW capabilities in the dedicated CAS aircraft. The result is a CAS airplane suited for day, clear weather operations only.

An attack version of the F-16, the A-16, is being advocated by the Air Force as the solution to performing CAS at night and in bad weather. The single-seat A-16, like the A-10A, should perform well in daylight CAS operations. However, according to Crawford and the CNA study, the A-16 crew complement is not optimized for night and bad weather scenarios (10:8; 8:26-27). The A-10B comes closest to meeting the criteria described in these two studies to perform CAS at night and in adverse weather.

In summary, the Air Force does not appear to be any closer to supporting the Army with night/adverse weather close air support. The A-10A lacks the crew complement and technology to perform the mission in a high threat environment. The A-16 will have the advanced technologies, but may suffer from the same shortcomings of the LANTIRN-equipped F-16. In performing night/adverse weather CAS missions, USAF planners appear to be relying solely upon advanced technologies to achieve the combat mission effectiveness required to support the US Army.

Literature Review Conclusions

The literature reviewed in this chapter indicates the Air Force is committed to the incorporation of leading edge cockpit technologies into new and existing aircraft. The chief benefit to the Air Force in pursuing new cockpit technology incorporation is the sizeable cost savings gained by eliminating aircrew positions. State-of-the art technologies make new aircraft less expensive and existing aircraft less expensive to operate.

The controversy surrounding the incorporation of new cockpit technologies is in the area of mission effectiveness. Mission effectiveness is not as easily measured as the dollar savings of eliminating an aircrew position. Mission effectiveness has no unit of measure. For example, the CNA study stated two-seat crews generally performed all F/A-18 Hornet missions better than a single-seat crew, but no universal quantitative scale or value exists that is understood or accepted. If this scale or value could be determined, perhaps a dollar value to each "unit" of mission effectiveness could be calculated. Such a relationship would obviously simplify the decision to eliminate aircrew members for "black boxes."

This literature review has highlighted the dilemma Air Force decision makers now face. Senior Air Force leadership is under pressure to cut the cost of maintaining an effective fighting force. Many of the studies reviewed in this literature search raise serious questions regarding Air Force decisions concerning advanced technology incorporation. For example: 1) acquiring the KC-10 to replace the KC-135--an initial acquisition goal that, after ten years of operational Extender experience, has yet to be realized; 2) modifying the F-16 Fighting Falcon into an all weather, day or night, dual role fighter without regard to possible pilot task overload; and 3) ignoring the likelihood the A-10 Thunderbolt II would have to perform its primary mission at night, when the Army, its beneficiary, plans to execute many of its combat operations. Sufficient doubt exists as to whether the Air Force is harnessing advanced cockpit technology correctly. There exists the possibility the Air Force may be sacrificing combat mission effectiveness by trading people for "black boxes." The optimal solution may be to retain aircrew skills <u>and</u> incorporate advanced cockpit technologies into a smaller, but more effective Air Force. This chapter of the research effort cannot verify the soundness of Air Force decisions in its use of advanced cockpit technologies. Further research is warranted.

No study, report, or Air Force source identified any factors critical to combat mission effectiveness. The studies and reports presented scenarios and recommendations on how each aircraft/crew complement could successfully negotiate each scenario. The individual factors that would lead to success were not revealed. The individual factors that make up combat mission effectiveness for each aircraft/crew complement deserve further research.

This literature review provides a jumping off point for more research to answer the research question: *Can the Nav/WSO/EWO effectively be replaced by new cockpit automation technologies on aircraft performing missions in high threat combat environments?* Air Force leadership, academic experts, or any amount of simulated studies cannot answer this question. One expert in this field is the user of the equipment: the Air Force pilot. Pilots are the only individuals who have dealt with the mental and physical stresses of flight. The Air Force possesses a population of pilots with recent combat experience (DESERT STORM). These aviators know whether or advanced cockpit technologies have adequately compensated for reduced aircrew complements. A sample of Air Force pilots can also identify the critical mission factors of their respective missions. The next logical step in this research effort is to obtain data from the best source (USAF pilots) that can point to possible answers to the research question.

III. METHODOLOGY

Chapter Overview

This chapter describes the methodology followed in this study. It includes a description of the population and sample from which data was collected. It also contains a description of the survey instrument that was used in the study and a discussion concerning survey construction and testing. The chapter concludes with a description of reliability and statistical tests used to analyze the data.

Population

At the outset of this study, in order to answer the research question posed in chapter one, the researchers intended to survey pilots in the following aircraft: B-52, B-1B, C-5, C-141, C130, KC-135, KC-10, F-4, F-15, F-15E, F-16, F-111, F-117, and A-10. The intent was to obtain data from pilots in as many types of aircraft as possible. The purpose was to gain an Air Force wide picture of pilot attitudes towards combat mission effectiveness factors for the aircraft they flew and to define their perspective on how the Nav/WSO/EWO contributed to their combat effectiveness. The sampling plan would have involved sending out approximately 2100 surveys to the various pilot groups.

The original plan was modified when Headquarters Air Force Military Personnel Center/Personnel Measurement Division (HQ AFMPC/DPMYOS) Randolph AFB, Texas, indicated it would not approve the surveying of such a large number of pilots. A policy was instituted in January 1990 reducing the number of surveys sent to U.S. Air Force pilots (22). According to a representative of HQ AFMPC/DPMYOS, the policy was the result of numerous pilot complaints that they were filling out too many surveys (24). In addition, HQ AFMPC/DPMYOS requested the researchers obtain a sponsor for the survey as it would be sent to pilots in all of the major commands. The sponsor for this survey was Aeronautical Systems Division/ Engineering (ASD/EN) at Wright-Patterson AFB, Ohio. In the final approval letter, HQ AFMPC/DPMYOS agreed to allow the researchers to gather data by sending surveys to no more than 800 pilots in the following aircraft: F-15E, F-16, KC-135, A-10, C-130, and B-52.

The F-15E and the F-16 were selected for study because both were used in the war in the Persian Gulf and each is tasked with performing identical missions however, the F-15E incorporates a two man crew while the F-16 uses a single pilot (44:164-165). The researchers believed the comparison of attitudes between pilots of the two aircraft would be particularly useful for examining critical mission effectiveness factors and the role of the Nav/WSO/EWO. The A-10 was selected because it flew Close Air Support (CAS) missions at night in the Persian Gulf war. Also, the A-10 is a single seat, single mission aircraft which provides a good contrast to the F-16. The researchers were interested in the pilots' perception about their abilities to effectively perform their missions in a combat environment without a Nav/WSO/EWO. The B-52 was selected for study due to its combat role in the Persian Gulf. In addition, the B-52 has performed strategic and conventional bombing effectively since the 1950s with a crew that includes two navigators and an EWO. Finally, the KC-135 and the C-130 were selected for study because the Air Force and ASD/EN is currently exploring ways to eliminate the navigator position in both aircraft.

The total number of pilots currently flying each airplane was supplied by HQ AFMPC/Operations Officer Assignments Division (DPMRO) at Randolph AFB, Texas. The numbers include all pilots in the grade of Lieutenant Colonel and below who were actively flying as of May, 1991 (4).

TABLE 3-1

USAF ACTIVELY FLYING PILOTS

Aircraft	Total number actively flying
B-52	852
KC-135	1564
C-130	996
A-10	660
F-15E	120
F-16	1457

Sample

The sampling plan for this study was limited due to a current restriction on all Air Force academic research. HQ AFMPC/DPMYOS has limited the sample size to that which will provide only a 90 percent level of confidence (plus or minus 10 percent) that the sample mean approximates the mean of the population. The preferred level of confidence is 95 percent (plus or minus 5 percent) for this type of research (42). The lower confidence interval reduces the total number of survey questionnaries circulated, lowers the overall costs of the research, and, because of the homogeneity of the population for each aircraft type, does not significantly affect the external validity of the results (18:287-295).

The sample size for each aircraft was calculated based on the total number in each population group using the following formula (31:607-610):

$$n = \frac{NZ^2 \times .25}{(d^2 \times (N-1)) + (Z^2 \times .25)} \qquad (1)$$

where

n = sample size required

N = total population size

d = precision or confidence level desired (.10)

Z = different factor for each confidence level (1.6449)

The minimum number of surveys required for a 90% level of confidence, the actual number of surveys mailed, and the actual number of surveys returned are reported below by aircraft.

TABLE 3-2

SURVEY DATA

Aircraft	# of surveys required	# of surveys mailed	# of surveys returned
B-52	63	126	83
KC-135	65	130	66
A-10	62	124	71
F-15E	44	88	53
F-16	65	130	74
C-130	64	128	57
Totals	363	726	404

The actual number of surveys mailed to respondents was determined by doubling the number of surveys required. Twice the number of surveys required were mailed based on a 50% return rate typically achieved on AFIT research projects.

The ATLAS database of HQ AFMPC was used to draw a random sample of each pilot group based on the Air Force Speciality Code (AFSC) for pilots from each aircraft. The sample was drawn from all pilots in a particular group who possessed one of the current AFSCs listed in the table below.

TABLE 3-3
AFSC DATA

Aircraft	AFSC
B-52	1235C & 1233C
KC-135	1065C & 1063C
C-130	1055B & 1053B
A-10	1115N
F-15E	1115B
F-16	1115Q

Individuals from each AFSC group with the final digit of their social security number ending in a seven, eight, or nine were randomly selected. A random sampling technique (as opposed to a convenience sample) was used to strengthen the external validity of the research. External validity is the ability to generalize a particular finding across different measures, settings, and populations (36:198). The researchers requested and received two sets of mailing labels. The second set of mailing labels was used to mail a follow-up letter approximately two weeks after the survey was mailed. The follow-up letter served a useful purpose for increasing the return rate, because some individuals received the follow-up letter, but for unexplained reasons had not received a survey. The follow-up letter prompted some individuals to call the researchers and ask for a survey.

Survey Instrument

After reviewing the various research methods available for data collection, the researchers decided the survey questionnaire would be the most appropriate for this research effort. A survey allows the gathering of current attitudinal data on pilots in an efficient, cost-effective, and timely manner. As noted in chapters one and two, little research has been accomplished concerning combat mission effectiveness factors and the impact of the Nav/WSO/EWO on those factors. Therefore, developing the survey required the composition of a significant number of original questions. The questions were designed to gather data on pilot attitudes about the criteria used to assess mission effectiveness in a combat environment and the navigator's contribution to mission effectiveness. The survey questionnarie was also designed to guarantee strict anonymity. No questions were asked about the respondents' name, social security number, or location. In addition, no effort was made to track the recipient of the survey. In spite of guarantees of anonymity, responses to mail surveys are often poor (16:185). The follow-up letter was used to help alleviate this problem.

Survey Construction and Testing

During survey construction great care was taken to not ask misleading or ambiguous questions. All questions were designed to allow each individual an appropriate response to each question asked.

Experience factors. The survey was composed of three main parts. Part I included 15 questions about demographic aspects of the respondent. These demographic variables included: rank, type of aircraft currently assigned, number of training flight hours, number of combat hours, number of total flying hours, other types of aircraft flown, previous rating as a Nav/WSO/EWO, previous or current flight time with a Nav/WSO/EWO, qualification as an instructor, evaluator, or Wing Weapons and Tactics Officer, and previous participation in any FLAG exercises or unit competitions. These questions were asked in order to determine the experience level of the pilot answering the survey.

Mission Effectiveness factors. Questions 16 to 46 comprised part II of the survey. Each question listed a specific mission effectiveness factor. The pilots were then asked to rate the degree of criticality of each factor as it applied to the successful performance of a combat mission flown in their particular aircraft. The various factors were drawn not only from the literature but were also based on the personal flight crew experiences of the authors. Each factor was selected according to its potential impact on the successful accomplishment of a combat mission. In addition, dicussions in the literature referred to these factors when describing the accomplishment of successful combat mission scenarios. Some of the factors described particular phases of the mission while others were more universal and affected all phases of the mission. In addition, some of the factors, such as flight safety, applied to all six types of aircraft surveyed, while others, such as high speed airdrop, applied to specific aircraft. Most of the factors were taken directly from the literature and were not specifically defined. Many of the factors conveyed different meanings according to the aircraft type and mission. For the purposes of this research, the factors were taken at their face value from the literature with the thought that the pilots responding to the survey would interpret the precise meaning of a particular factor in their own operational contexts.

The factors were listed in general terms so that they would apply to a wide audience. This research effort does not attempt to precisely define or establish specific criteria for mission effectiveness factors. The goal, in general terms, is to determine if any of the mission effectiveness factors, as discussed in the literature, are critical to a particular mission.

The validity of the selected factors was tested by administering a pre-test of the survey to pilots in five different aircraft types. The purpose was to determine if the factors accurately described appropriate areas of mission effectiveness. The final list of combat effectiveness factors included the changes recommended by the pre-test group. All 31 factors are listed below as drawn from the literature, with sources indicated, and in the order they appeared in the survey.

1. Ability to Fly in Adverse Weather/Low Inflight Visibility (23:7)
2. Mission Planning
3. Monitoring On-Board Avionics & Weapon Systems (6:22)
4. Flight Safety (20:1)
5. Equipment Degradation During Mission (37:1)
6. Low Level Navigation (6:1)
7. Night Low Level Navigation (9:4)
8. Threat Avoidance (30:37)
9. Formation Management (19:2)
10. Management of Time Over Target (TOT) (8:11)
11. Inflight, No-Notice Mission Changes (37:1)
12. Targets of Opportunity (20:1)
13. Munitions Employment (8:5)
14. Threat Detection (23:7)
15. Level of Aircrew Taskings (29:3)
16. Ability to Handle Crew Member Incapacitation (40:13)
17. Ability to Handle Inflight Emergencies (37:1)
18. Visual Lookout (23:7)
19. Command & Control (Includes copying and decoding EAMS) (29:4)
20. Crew Fatigue
21. Crew Coordination (20:1)
22. Aircraft Maneuvering (To avoid air and ground threats and no fly areas) (37:1)

23. Situational Awareness (20:1)

24. Target Acquisition (23:7)

25. Visual Drop Capability

26. Night Operations (19:3)

27. High Speed Air Drop (19:4)

28. Station Keeping (40:23)

29. Aircrew Workload (37:1)

30. Short-Unimproved Airfield Operations (19:3)

31. Terrain Avoidance/Following (23:11)

Each respondent rated each mission effectiveness factor using a five point Likert scale with the following response choices:

Always Critical To Mission Success

Almost Always Critical To Mission Success

Can Be Critical

Almost Never Critical

Never Critical

At the end of the list of factors, the respondents were given the opportunity to list any additional factors they felt were always critical to the success of a combat mission.

Nav/WSO/EWO Impact on Mission Effectiveness. Questions 47 through 80 solicted information regarding pilot perception of the impact of a Nav/WSO/EWO on the combat mission the pilots might fly. The questions were designed to assess the pilots' perception of not only the impact of the Nav/WSO/EWO on critical combat effectiveness factors but also the requirement for a Nav/WSO/EWO based on a particular type of combat mission. Two variables were created by the researchers to attempt to measure pilots' perception of the potential impact of a Nav/WSO/EWO on combat missions: NAVCRIT and REQ.

NAVCRIT. NAVCRIT is a variable which measures the impact of a Nav/WSO/EWO on the specific combat mission effectiveness factors selected as critical by a particular pilot. The assumption was made that if a pilot of a particular aircraft selected any of the mission effectiveness factors as critical, then an attempt could be made to determine how the Nav/WSO/EWO contributed to the successful accomplishment of the critical mission effectiveness factors. Eight questions were used from the survey to form a composite score of the Nav/WSO/EWO's contribution to successfully accomplishing critical mission effectiveness factors. Multiple questions were used to arrive at a composite score of NAVCRIT, because according to Mitchell, multiple items improve the construct validity of the investigative question (36:203). Some of the questions were worded in a general sense that did not focus on the presence of a Nav/WSO/EWO in an individual pilot's aircraft. Others specifically asked about the presence of a Nav/WSO/EWO in an individual pilot's aircraft and the ability of the Nav/WSO/EWO to enhance the performance of the pilot. Questions 47, 50, 51, 57, 58, 62, 63, and 73 were used to measure NAVCRIT. The eight questions are listed below.

47. The Navigator/WSO/EWO is a critical resource on the airplane I am currently qualified to fly.

50. I can perform my assigned wartime mission without a Navigator/WSO/EWO.

51. The addition of a Navigator/WSO/EWO to my airplane would increase the overall mission effectiveness of my taskings.

57. The Navigator/WSO/EWO is vital on night low-level, wartime missions.

58. A Navigator/WSO/EWO in my airplane would enhance the combat effectiveness of the factors I selected as always critical to mission success.

62. I would feel completely confident in my abilities to conduct a safe wartime mission if the Navigator/WSO/EWO were replaced with new cockpit automation technologies.

63. The Navigator/WSO/EWO can be essential during inflight emergencies.

73. In actual combat, a Navigator/WSO/EWO would be critical to performing an effective mission.

Responses to these questions indicate a measure of a pilot's perception of a Nav/WSO/EWO's ability to enhance critical mission effectiveness factors. An individual's responses to the questions and the overall NAVCRIT score will naturally reflect the bias of the individual's personal background and experiences.

By taking all of the answers to the questions together, the researchers were able to obtain an accurate assessment of a pilot's perception about the impact a Nav/WSO/EWO would have on selected critical combat mission effectiveness factors.

REQ. REQ was the variable the researchers used to measure a pilots' perception of the requirement for a Nav/WSO/EWO for a specific mission. REQ was created to determine if the requirement for a Nav/WSO/EWO is based on a specific mission instead of any particular group of combat effectiveness factors. Five questions were used to form a composite score for the requirement for a Nav/WSO/EWO on a specific mission. As discussed previously, multiple questions improve the construct validity of the investigative question. Some of the questions were generally worded and did not focus on the requirement for a Nav/WSO/EWO for the pilot's specific mission, while others were worded to ask specifically about the requirement for a Nav/WSO/EWO on the pilot's particular mission. Questions 48, 53, 54, 66, and 67 were used to measure REQ. The five questions are listed below.

48. An aircraft designed to perform more than one type of mission should have a Navigator/WSO/EWO as part of the crew.

53. Certain missions require a Navigator/WSO/EWO to be successful.

54. Certain missions I currently perform require a Navigator/WSO/EWO to be successful.

66. The Advanced Tactical Fighter (ATF) should have a two person crew (a Pilot and Weapon System Officer).

67. A Navigator/WSO/EWO is required on some missions due to the complexity of the mission and pilot workload.

Responses to these questions indicate a measure of a pilot's perception of the requirement for a Nav/WSO/EWO depending on the type of mission. Once again, an individual's responses to the questions and the individual's overall REQ score will naturally reflect the bias of personal background and experiences. Combining the responses to all five questions enabled the researchers to obtain an accurate assessment of the pilots' perception of the requirement for a Nav/WSO/EWO based on the mission.

The respondents used a five point Likert scale to answer the questions in part III of the survey. The scale used the following response choices:

Strongly Agree

Somewhat Agree

No Opinion

Somewhat Disagree

Strongly Disagree

At the conclusion of the survey, respondents were invited to comment on any of the topics presented in the survey.

Survey Pre-testing. Because the survey involved many original questions, a pre-test of the survey was necessary. Emory points out that the importance of the test-revise-retest cycle cannot be overstressed. The failure to take this important step is one of the greatest causes of poor sampling results (18:207). A pre-test of the survey was administered to the following three groups: 1) pilots in the 89th Tactical Fighter Squadron (TFS) at Wright-Patterson AFB, Ohio; 2) several pilots attending the Air Force Institute of Technology (AFIT) School of Engineering, and 3) several pilots who were personal acquaintances of the researchers. Ten F-16 pilots, one B-52 pilot, two C-130 pilots, one KC-135 pilot, and one F-4 pilot were pretested.

Of the 30 surveys administered to the 89th TFS, only 10 were returned. No comments were made on any of the ten surveys, even though the researchers asked for any problem areas to be identified. Analysis of the ten returned surveys did illuminate potential problems. The most helpful comments were made by the individuals attending AFIT and the researchers' personal acquaintances. The survey structure and question wording were modified based on their comments and personal interviews. For example, certain questions that were designed using a Guttman scale for responses were found to be universally confusing and were re-written.

Statistical Analysis of the Survey Data

The four investigative questions discussed in Chapter I were evaluated by statistically analyzing the survey responses. Evaluating the four investigative questions enabled the researchers to draw conclusions about the overall research question: Do pilots believe the Nav/WSO/EWO can effectively be replaced by new cockpit automation technologies on aircraft performing missions in high threat combat environments?

To explore conclusions to investigative question one, which asked, What do the pilots of a particular aircraft type believe are the critical mission effectiveness factors for the mission they perform, questions 16 through 46 of the survey were used. For each of the aircraft type in this study, the responses to a particular question were summed and divided by the total number of respondents to arrive at an average numerical value to determine how critical that particular mission effectiveness factor was to combat mission effectiveness. If the average value for a mission effectiveness factor was determined to be 1.599 or less, the researchers concluded it was always critical to mission success; between 1.600 and 2.599, the mission effectiveness factor was considered to be almost always critical to mission success; between 2.600 and 3.599, it was consider to be sometimes critical; between 3.600 and 4.599, it was considered as almost never critical, and over 4.500, the factor was considered never to be critical to mission success. The always critical and almost always critical mission effectiveness factors for each aircraft type were placed in separate tables and are presented in chapter IV.

Investigative question two, which asked, Do the pilots of a particular aircraft type believe a Nav/WSO/EWO would enhance the performance of their aircraft concerning critical mission effectiveness factors for the mission they perform, was explored using responses to the combined eight survey questions mentioned above to create the variable NAVCRIT. An overall value of NAVCRIT for each individual respondent was determined by summing the responses to all eight questions. The value of NAVCRIT could range between a maximum score of forty and a minimum score of eight. Respondents showing a NAVCRIT score of forty strongly believe a Nav/WSO/EWO is necessary to effectively perform selected critical mission effectiveness factors. A score of eight indicates they strongly do not believe a Nav/WSO/EWO is necessary to effectively perform selected critical mission effectiveness factors.

Cronbach's alpha and a Principal Component Analysis were performed on the eight questions using the SAS statistical analysis package. Cronbach's alpha is a correlational analysis that measures the internal consistency from one set of measures to another set of measures (39:213). It calculates a correlation (Cronbach's alpha) of each variable or question and the total of the remaining variables (39:214-215). Principal Component

Analysis looks for underlying patterns of relationships that exist between the survey questions that comprise NAVCRIT (38:469). This analysis also finds the smallest number of survey items that account for the variance in the data (38:479). The purpose of performing Cronbach's alpha and the Principal Component Analysis was to ensure the questions selected for NAVCRIT were related and were measuring the same factor. In addition, an overall average NAVCRIT score was determined for each aircraft. The mean NAVCRIT score for each aircraft type was compared to the overall mean scores of each of the other aircraft at the 95% confidence level using the Bonferroni t-test procedure in the SAS statistical analysis package. The Bonferroni procedure is a simple and statistically conservative test used for multiple comparisons of means using the t-distribution. The comparison of means between aircraft types enabled the researchers to determine if there was a statistical difference in attitudes between pilot groups concerning the impact of the Nav/WSO/EWO on selected combat effectiveness factors.

Investigative question three, which asked, Does the perception of the need for a Nav/WSO/EWO depend on the type of mission flown, was investigated using the variable REQ. An overall value of REQ was obtained for each respondent by summing the responses to the five questions mentioned above. Each respondent could total a score for REQ between twenty five and five. A score of twenty five indicates the pilot strongly believes the requirement for a Nav/WSO/EWO depends on the mission. A score of five indicates the pilot does not strongly believe the requirement for a Nav/WSO/EWO depends on the mission.

Cronbach's alpha and a Principal Component Analysis were also performed on the five questions comprising REQ using the SAS statistical analysis package. Cronbach's alpha and the Principal Component Analysis were means to improve the internal construct validity of REQ and NAVCRIT. In addition, an overall average REQ score was determined for each aircraft. As with NAVCRIT, the mean REQ score for each aircraft type was compared to the overall mean scores of each of the other aircraft at the 95% confidence level using the Bonferroni t-test procedure in the SAS statistical analysis package. The usefulness of the Bonferroni procedure has been discussed above. The comparison of means between aircraft types enabled the researchers to determine if there was a statistical difference in attitudes between pilot groups concerning the requirement for a Nav/WSO/EWO on aircraft performing different missions.

Finally, investigative question four, which asked, Does the perception of the need for a Nav/WSO/EWO depend on the experience level of the pilot, was explored by correlating the NAVCRIT and REQ scores for each respondent to experience factors of each respondent identified in part I of the survey. Thirteen of the questions in part I of the survey were used to assess the experience level of a particular pilot. The thirteen questions used are listed below. Each is considered an independent variable for the regression model.

1. What aircraft do you currently fly?
2. How many flying hours have you accumulated in the aircraft you are currently flying?
3. How many total flying hours have you accumulated?
4. Prior to being qualified in the aircraft you selected in question 1, were you qualified to fly any other operational, NOT trainer, aircraft?
5. Have you ever flown an airplane that included a Navigator/WSO/EWO as part of the crew?
6. How much combat time have you accumulated in the aircraft you are currently qualified to fly?
7. How much total combat time have you accumulated as a military pilot?
8. How much combat time did you accumulate as a Navigator/EWO/WSO?
9. Have you ever been qualified as an Instructor Pilot in an operational, NOT trainer, aircraft?
10. Have you ever been qualified as a Flight Evaluator in an operational, NOT trainer, aircraft?
11. Have you ever been qualified as a Wing Weapons & Tactics Officer in an operational, NOT trainer, aircraft?

12. Have you flown in any exercises (FLAG exercises), unit competitions (WILLIAM TELL, SAC Bombing Competitions, or Reconnaissance Air Meet), or any joint exercises as a participant?

13. What is your current rank?

The purpose was to determine if any one or combination of experience factors (independent variables) made a difference in the NAVCRIT or REQ scores (dependent variables) of a particular pilot. In addition, the researchers were interested which of the experience factors could be used to accurately predict NAVCRIT and REQ scores.

The Stepwise regression routine on the SAS statistical analysis package was used to determine the relevant experience factors. Stepwise regression is a systematic approach to building a regression model with a large number of independent variables. It is a useful screening process because it easily interprets multivariable interactions and high-order polynomials (34:722). The result of the stepwise regression is a model containing only those terms with t values that are significant at the specified alpha level. Thus, in most practical situations, only several of the large number of independent variables will remain (34:723). The alpha level for this research effort was set equal to .05 (95% confidence level).

Data Processing

Included with each survey was an optical character reader (OCR) answer sheet on which respondents made their responses. When the surveys were returned, they were checked to ensure they had been filled out properly and then were optically scanned. The data was stored in computer data files for statistical analysis.

Statistical Tests

The SAS statistical analysis package was used to determine frequency of responses, compute means, compute results of Bonferroni t-tests, perform a reliability analysis, and perform a stepwise regression routine on the experience factors.

Summary

This chapter identified the population and sample size of the pilot groups on which this research effort was focused. In addition, it discussed how the survey was constructed and pre-tested to gather accurate data to determine critical mission effectiveness factors for six different types of aircraft. Furthermore, it explained two variables created by the researchers, NAVCRIT and REQ, to not only assess pilot perception of the impact of the Nav/WSO/EWO on selected critical mission effectiveness factors but also determine if the requirement for a Nav/WSO/EWO was mission dependent. Finally, this chapter discussed how stepwise regression would be used to look for significant correlations between the selected pilot experience factors and associated NAVCRIT and REQ scores.

IV. DATA ANALYSIS

Chapter Overview

This chapter describes the data received from US Air Force pilots who elected to participate in this research. The survey instrument used to conduct this study can be found in Appendix A. This portion of the study is divided into three sections: demographics, analysis of critical combat mission effectiveness factors, and an analysis of the navigator critical and navigator required measures. Each section will present the data gleaned from the survey instrument and discussion of unusual or surprising aspects of the data.

Demographics

Figure 4-1 illustrates the responses received to the survey instrument segregated by type of aircraft the respondent is currently qualified to fly. One aircraft, the C-130, did not receive enough responses to achieve the desired 90 percent confidence interval for statistical analysis. The C-130 data contains 57 (89.6 percent) responses of a required 64 responses. Despite the survey response shortfall of this aircraft, the data gained from surveyed C-130 pilots will be useful in identifying trends in the aircraft population. The C-130 data does not possess

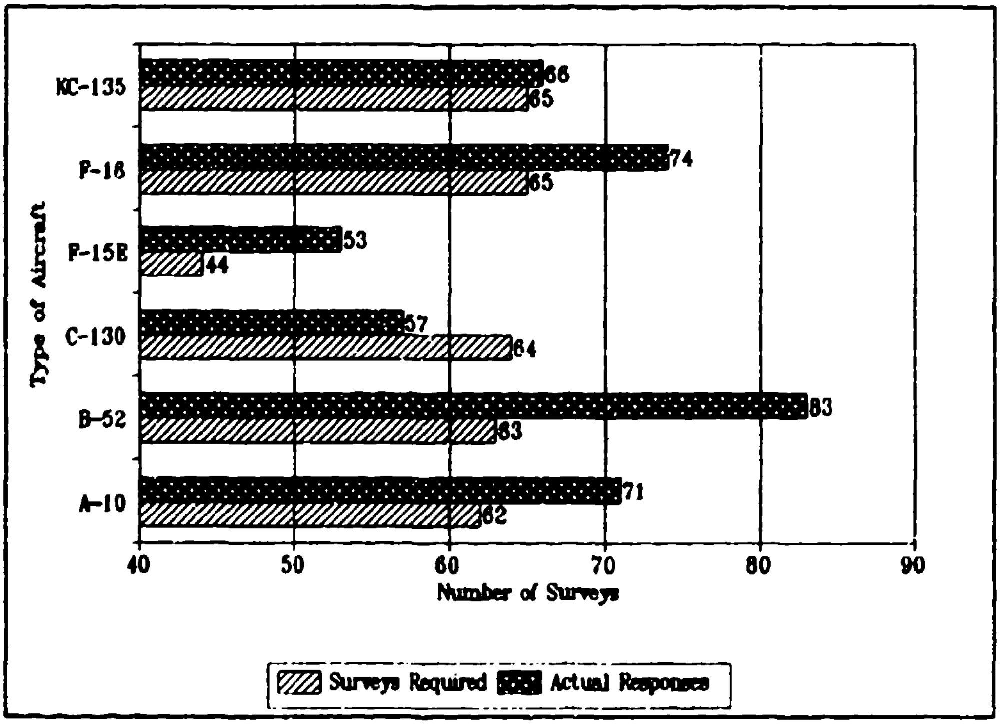

Figure 4-1. Number of Surveys Required for a 90 Percent Statistical Confidence Interval and Number of Surveys Returned by Aircraft Type

the statistical rigor of the other five aircraft types, but the data from the C-130 respondents is still valuable and will be included in data analysis and research study conclusions. Discussion/analysis of C-130 aircraft data is not at the same level of confidence as discussion/analysis of the A-10, B-52, F-15E, F-16, and KC-135 aircraft.

Many C-130 pilots telephoned the authors of this study several weeks after the survey was mailed to state that all Air Force C-130 units were heavily tasked with temporary duty (TDY) assignments around the world. The pilots stated the heavy TDY assignment workload prevented them from receiving the survey instrument until they returned from TDY. Many pilots were still deployed to the Persian Gulf providing humanitarian aid to the Kurds in Iraq (Operation PROVIDE COMFORT). Others were deployed to the Republic of the Philippines to provide military dependent airlift from Clark AB as a result of recent volcanic activity in the area.

Figure 4-2 depicts the military rank distribution of the research sample. Almost 60 percent of all respondents are captains. This high percentage of aviators in the grade of captain is representative of the Air Force population. Most actively flying Air Force officers have been commissioned in the Air Force from approximately four to ten years. This amount of commissioned time coincides with the time an officer would hold the rank of captain.

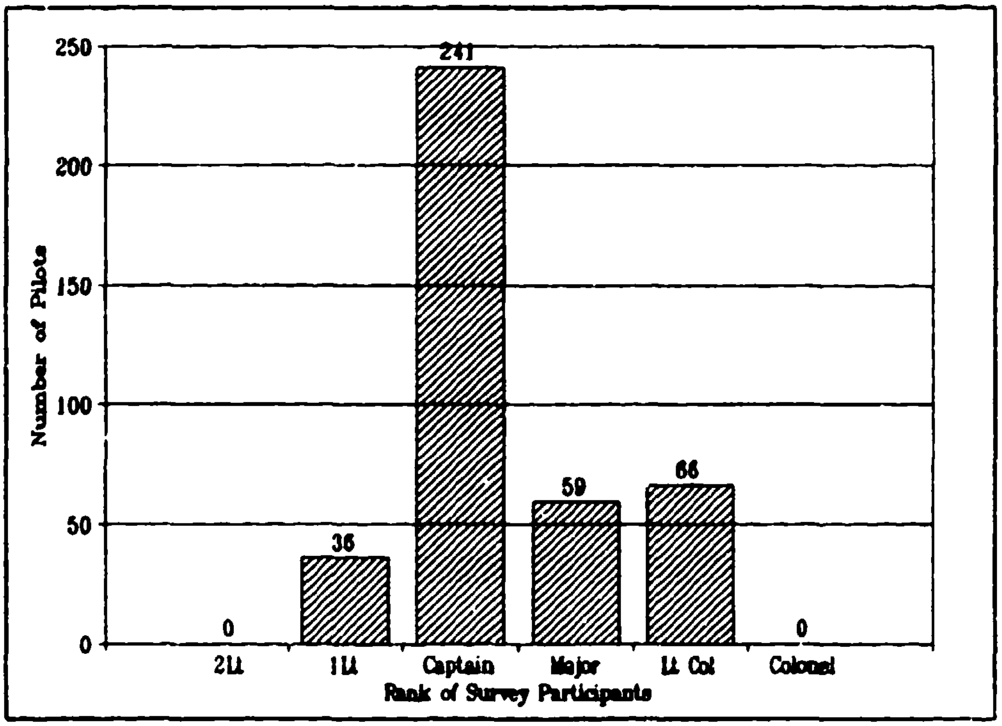

Figure 4-2. Number of Survey Participants by Military Rank

The remainder of the demographic data measures the survey participants' flying qualifications and experience as an aviator. The areas measured were: 1) the amount of flying time pilots had accumulated to date in their present aircraft; 2) the total amount of military flying time the respondents had accumulated during their career; 3) the amount of combat time accumulated in the respondents' current aircraft; 4) the total amount of combat time individuals had accumulated over their entire career. Other areas of interest included aircraft qualifications such as instructor pilot qualification, flight evaluator qualification, wing-level weapons and tactics officer qualification, and participation in any military exercise or competition.

Figures 4-3 and 4-4 present the amount of flying time each respondent has accumulated in the six aircraft that make up this study. Two figures are used to depict many of the flying experience measures. This approach of dividing the figures into "heavy" aircraft and fighter-attack aircraft serves two purposes. The first consideration is the difference in flying hour accumulation--most fighter-attack aircraft sorties are less than two hours in duration. In contrast, most "heavy" aircraft sortie duration is greater than four hours. This difference in sortie duration can result in bomber, transport, and tanker pilots accumulating many more flying hours in a shorter period of time. For example, a fighter-attack pilot with 500 flying

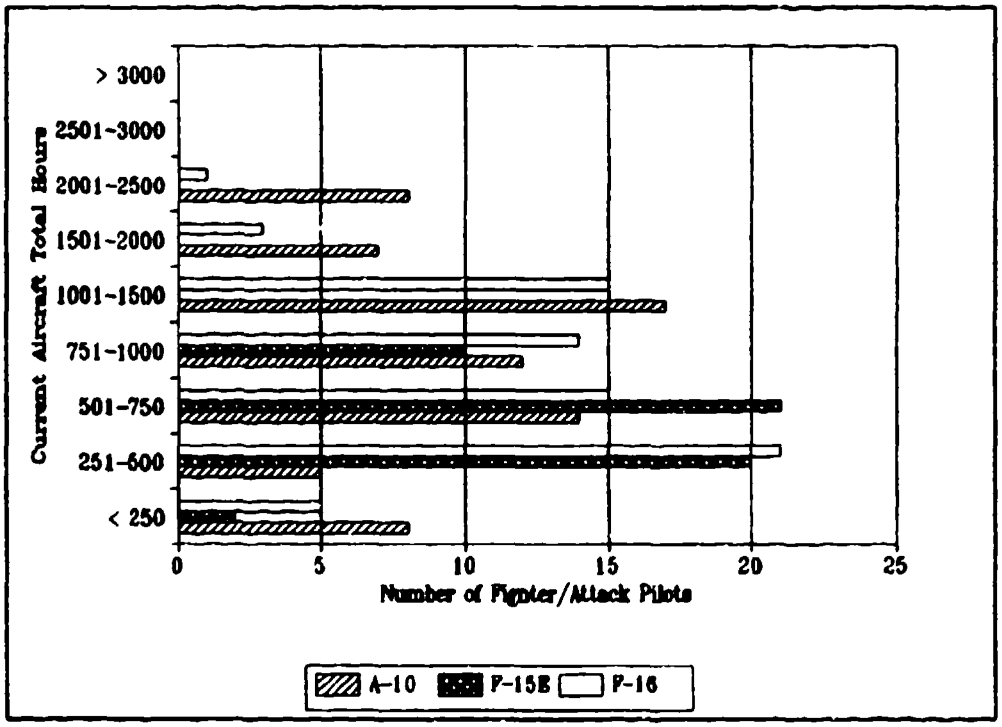

Figure 4-3. Accumulated A-10, F-15E, and F-16 Flying Time of Survey Respondents

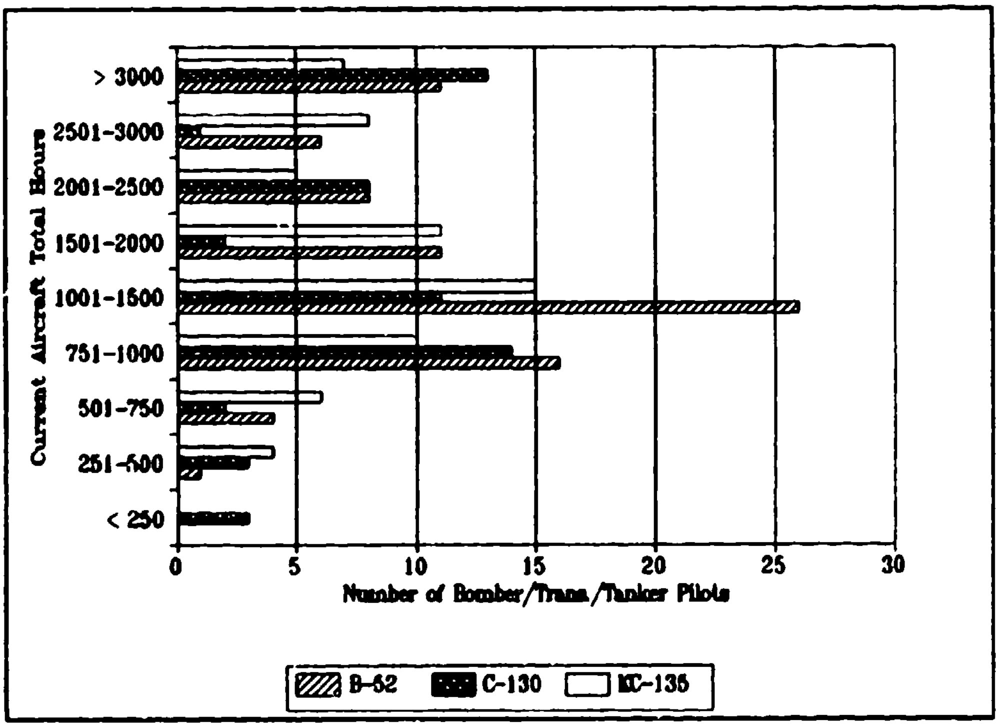

Figure 4-4. Accumulated B-52, C-130, and KC-135 Flying Time of Survey Respondents

hours is considered "experienced." A "heavy" pilot is "inexperienced" until accumulating over 1,000 hours. Comparison of "heavy" pilot flying time to other "heavy" flying time is a truer representation of experience.

The second consideration in dividing the sample into "heavy" and fighter-attack graphic representations is visual presentation. A graph with all six aircraft depicted would be cluttered and unreadable. A division of the survey sample will help the reader understand each graphic more clearly.

Figure 4-5 shows that approximately one third of the respondents were previously qualified in at least one other operational military aircraft earlier in their military careers. The impact of additional aircraft qualification(s) on these pilots' total military flying hours is depicted in Figures 4-6 and 4-7.

Figures 4-3, 4-4, 4-5, 4-6, and 4-7 show a sample population that is generally very experienced. Almost eighty-nine percent of the pilot sample possess over 1,000 total military flying hours. The high experience level of the survey sample adds credibility to the findings and opinions expressed in this study.

The experienced make-up of the survey sample can also be attributed to the high number of pilots (203 or 52.2 percent) who have been qualified as instructor pilots in operational Air Force aircraft. The aviators are usually highly experienced and remain at the squadron level to teach

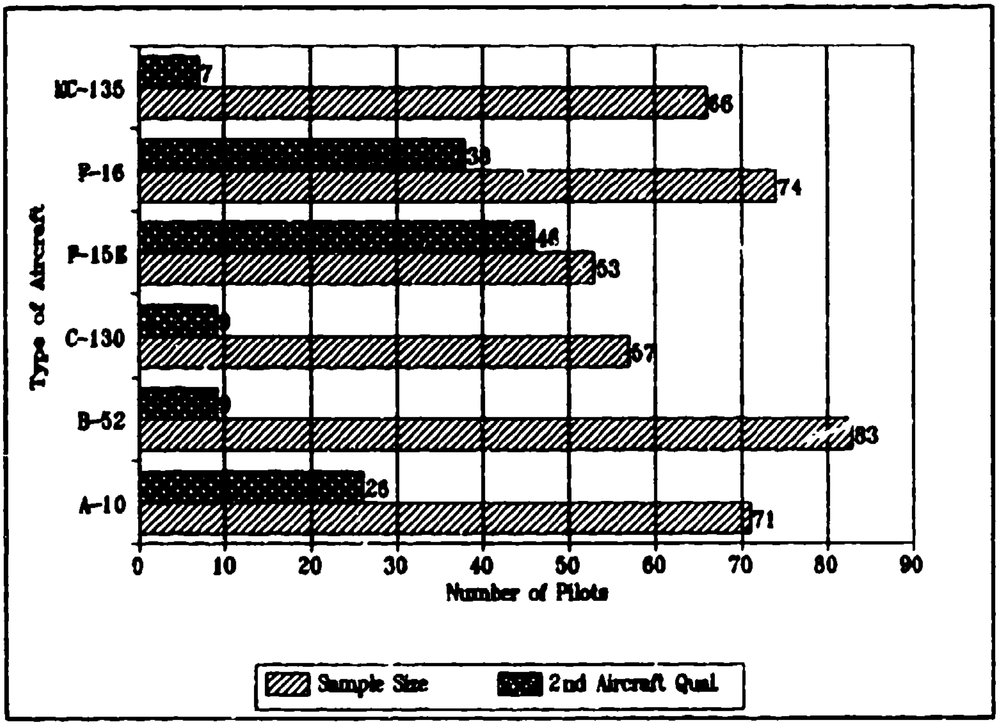

Figure 4-5. Survey Respondents Previously Qualified in Other USAF Operational Aircraft

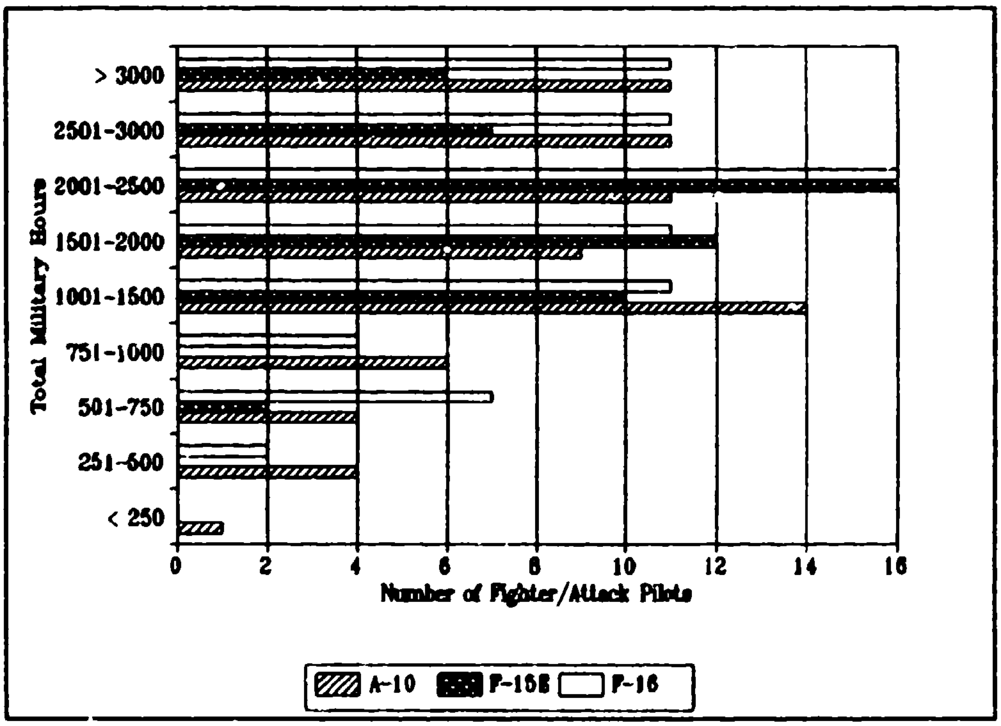

Figure 4-6. Total Military Flying Time of A-10, F-15E, and F-16 Survey Participants

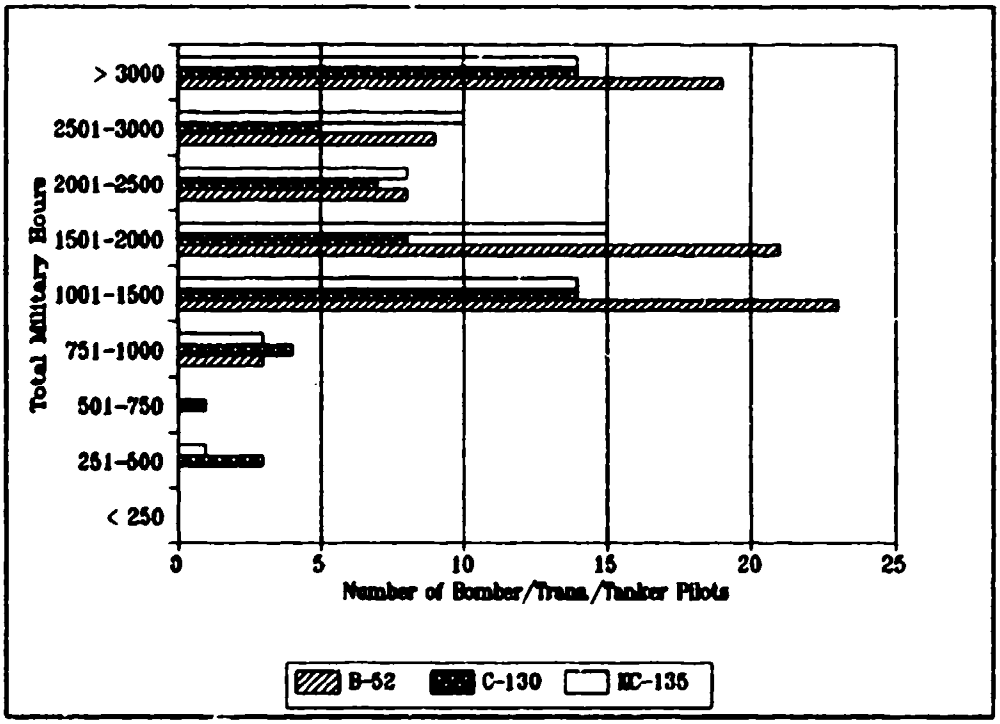

Figure 4-7. Total Military Flying Time of B-52, C-130, and KC-135 Survey Participants

and qualify other squadron aircrew members in the unit's wartime mission. Almost all pilots surveyed, 90.3 percent, have participated in combat-simulating flying exercises or command-sponsored flying competitions. Figures 4-8 and 4-9 present visual depictions of survey participants who have been qualified as instructor pilots and have participated in flying exercises or competitions.

The survey sample also possessed a relatively high number of pilots who have held the wing level positions of flight evaluator and tactics officer. The wing flight evaluator position is usually manned by a highly experienced individual who is already qualified as an instructor. This individual is tasked with evaluating other aviators in their flying ability to perform the unit's wartime mission. The wing tactics officer is also an instructor who is tasked with teaching and establishing the wartime flying tactics a wing will use in the event of hostilities. Figures 4-10 and 4-11 visually depict the flight evaluators and tactics officers who answered the survey.

Over 50 percent of the survey sample have accumulated combat flight hours. This special category of flying time can be accumulated only when authorized by the Department of Defense. Almost all of the combat time logged by survey participants is from Operation DESERT STORM. Slightly less than three percent of the respondents possess combat flying time from other hostile actions--Vietnam, the Grenada invasion, and Operation JUST CAUSE (the invasion of Panama).

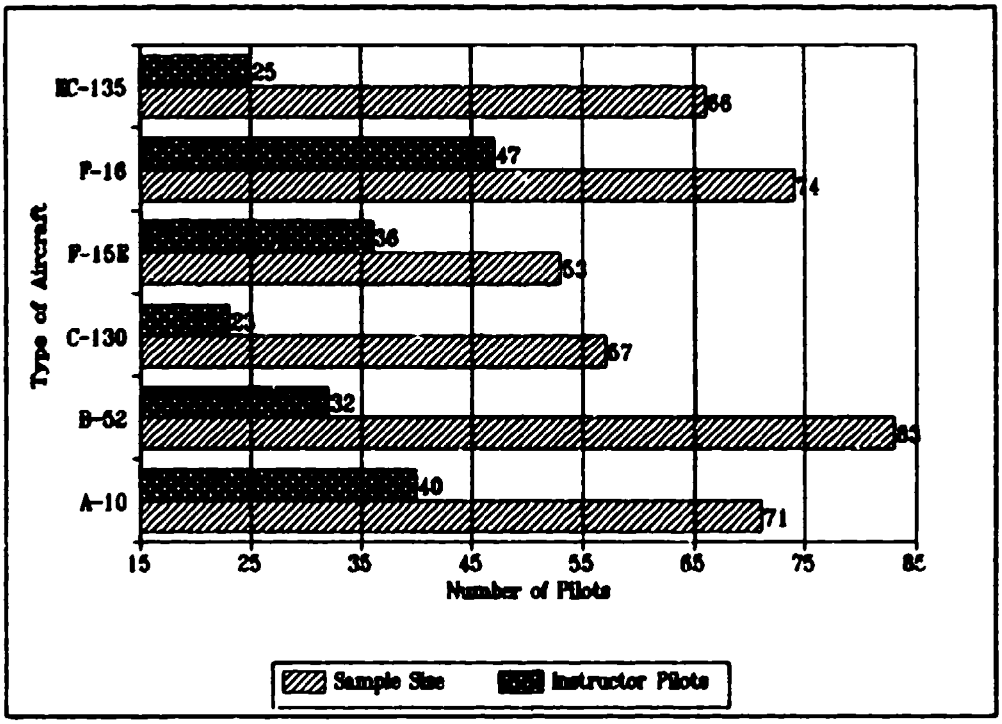

Figure 4-8. Survey Respondents Qualified as USAF Flight Instructor Pilots

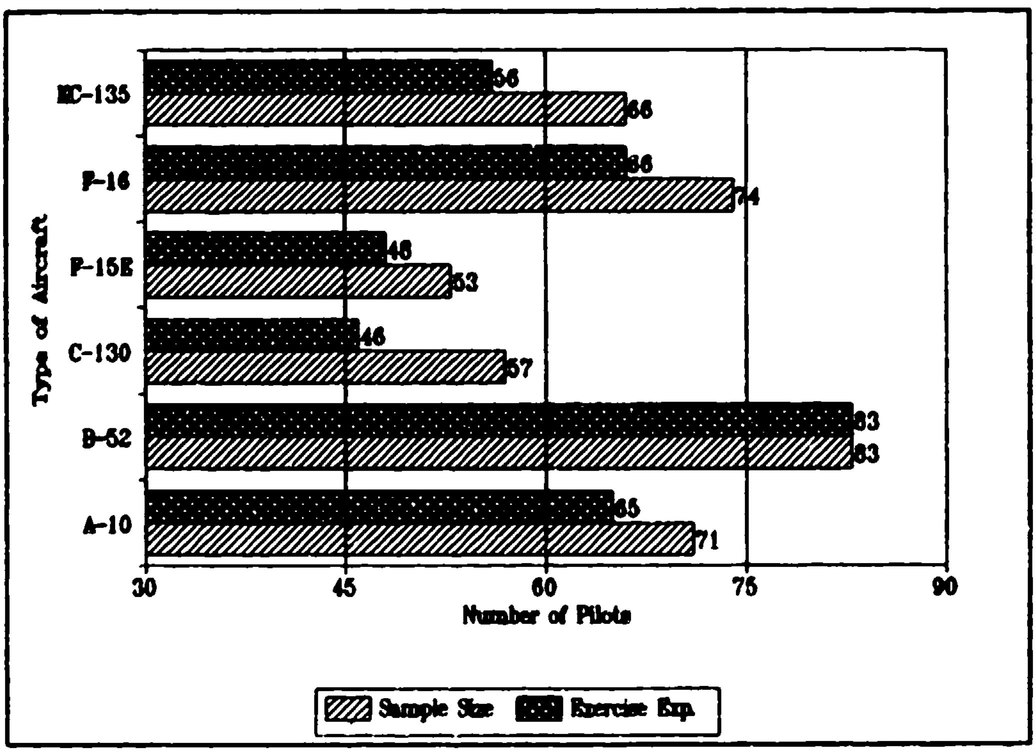

Figure 4-9. Respondents Who have Flown in Command-Sponsored Flying Exercises or Competitions

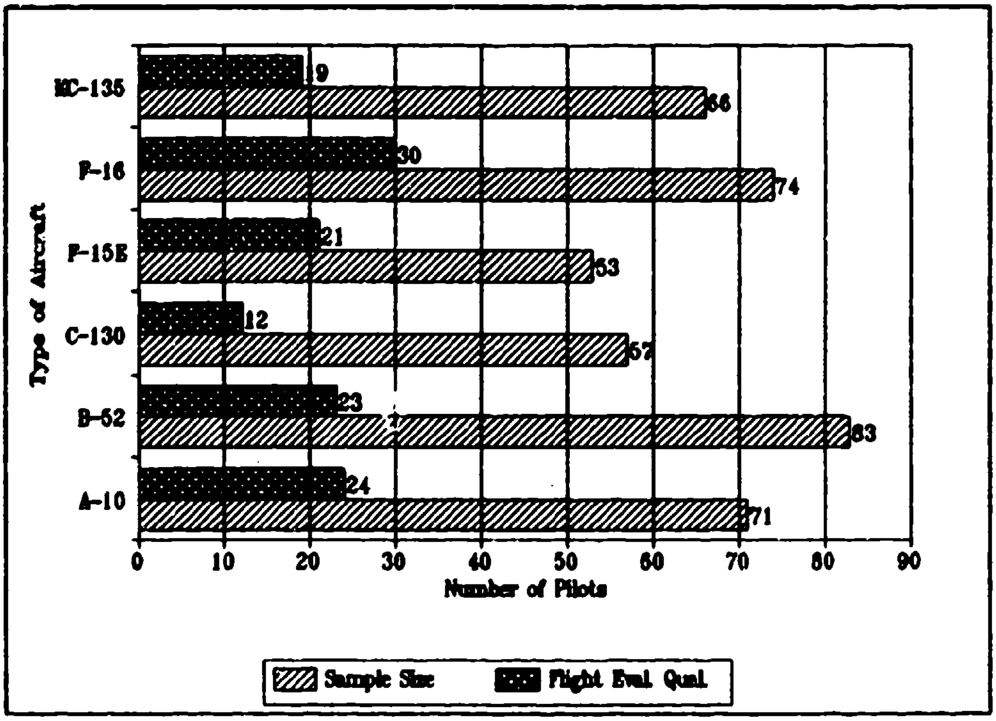

Figure 4-10. Survey Participants Qualified as USAF Flight Evaluators

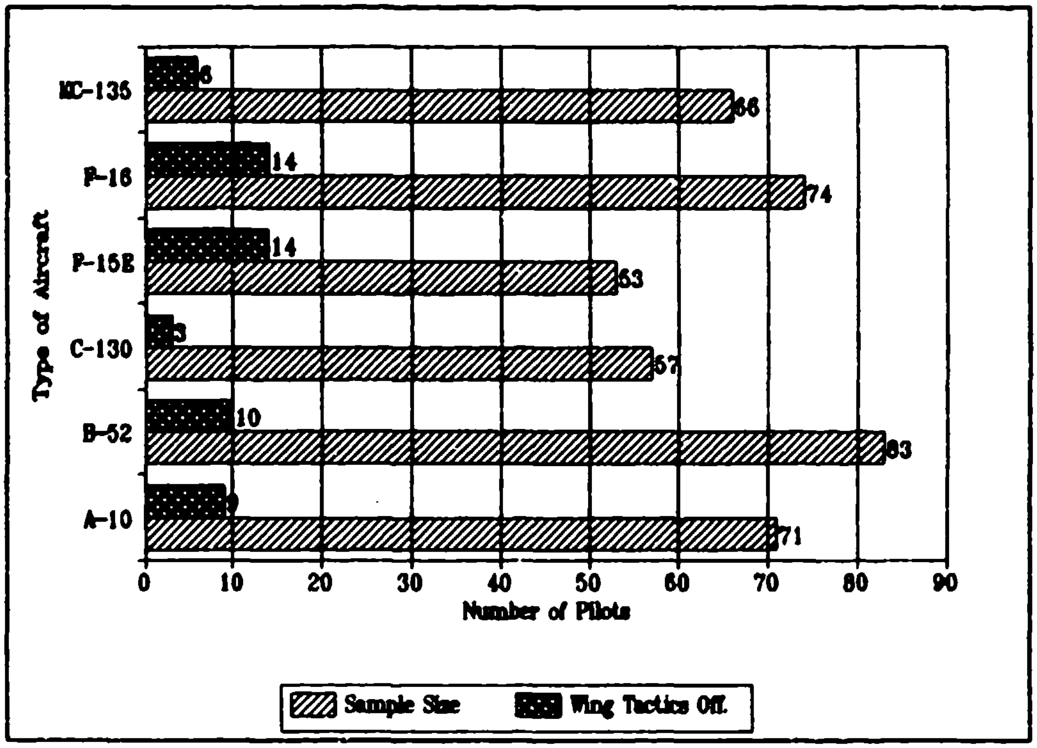

Figure 4-11. Survey Respondents Qualified as Wing-Level Weapons and Tactics Officers

Figures 4-12 and 4-13 graphically depict accumulated combat time of the survey respondents in the aircraft they are currently qualified to fly (B-52, C-130, KC-135, A-10, F-15E, or F-16). Figures 4-14 and 4-15 illustrate <u>total</u> combat hours accumulated. These two graphs take into account the fact that some pilots flew and fought in other aircraft prior to becoming qualified in one of the six aircraft sampled in this research.

Combat time is an important experience factor in this research. These pilots have tested the aircraft, tactics, and advanced cockpit technologies of the modern Air Force in actual combat. Capturing the ideas, feelings and comments of pilots with recent combat experience is invaluable in answering the research question of this research.

A small portion of the sample population possessed a unique facet of experience. Twenty-two (5.4 percent) of the sample were rated as Air Force navigators prior to becoming pilots. Seven of the twenty-two pilots surveyed have combat experience as navigators. This group has experienced both sides of the advanced cockpit technologies issue. They have flown in the navigator position, generally the target of replacement by advanced cockpit technologies, and as pilots, the users of advanced cockpit technologies. Figures 4-16 and 4-17 graphically illustrate navigator combat time of the pilots surveyed.

In summary, an examination of the demographics of pilots sampled for this study reveals a highly experienced

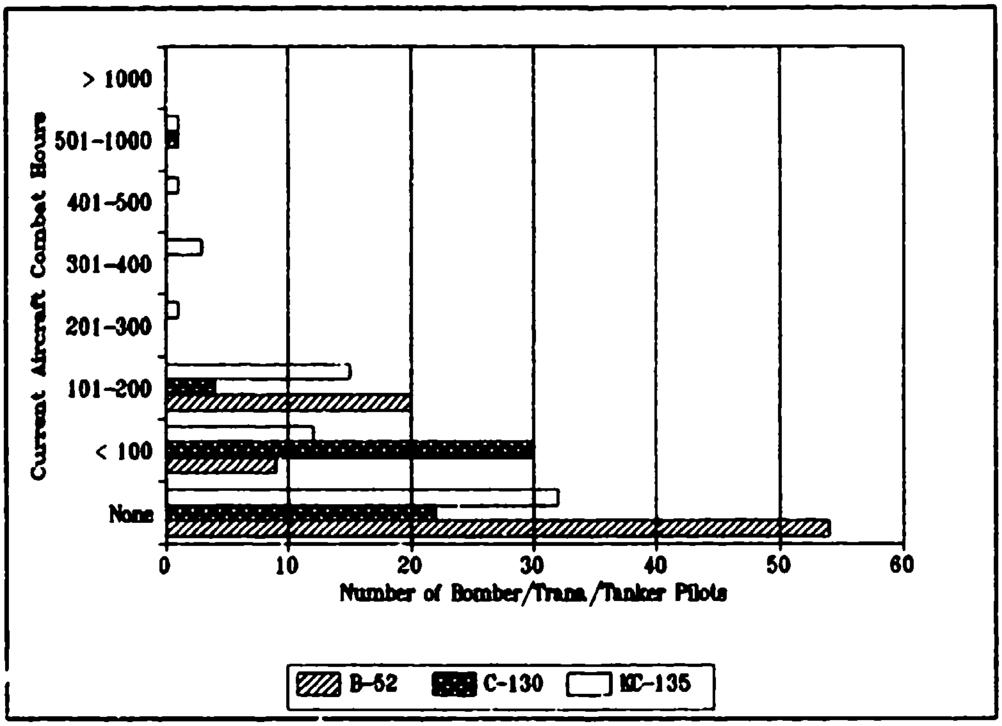

Figure 4-12. Combat Experience of B-52, C-130, and KC-135 Respondents

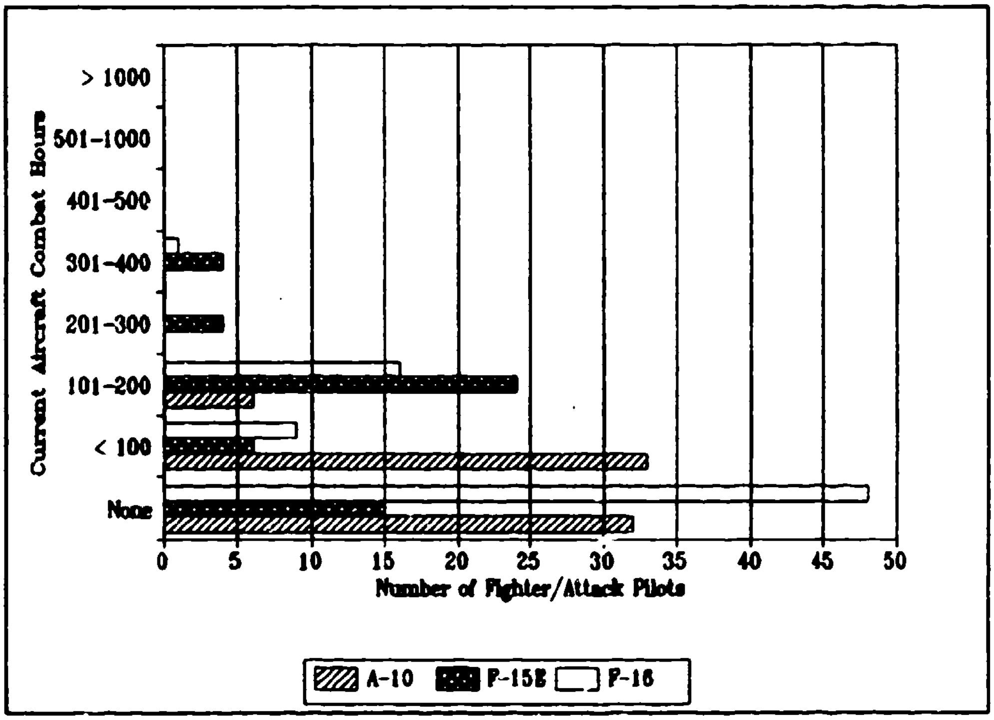

Figure 4-13. Combat Experience of A-10, F-15E, and F-16 Respondents

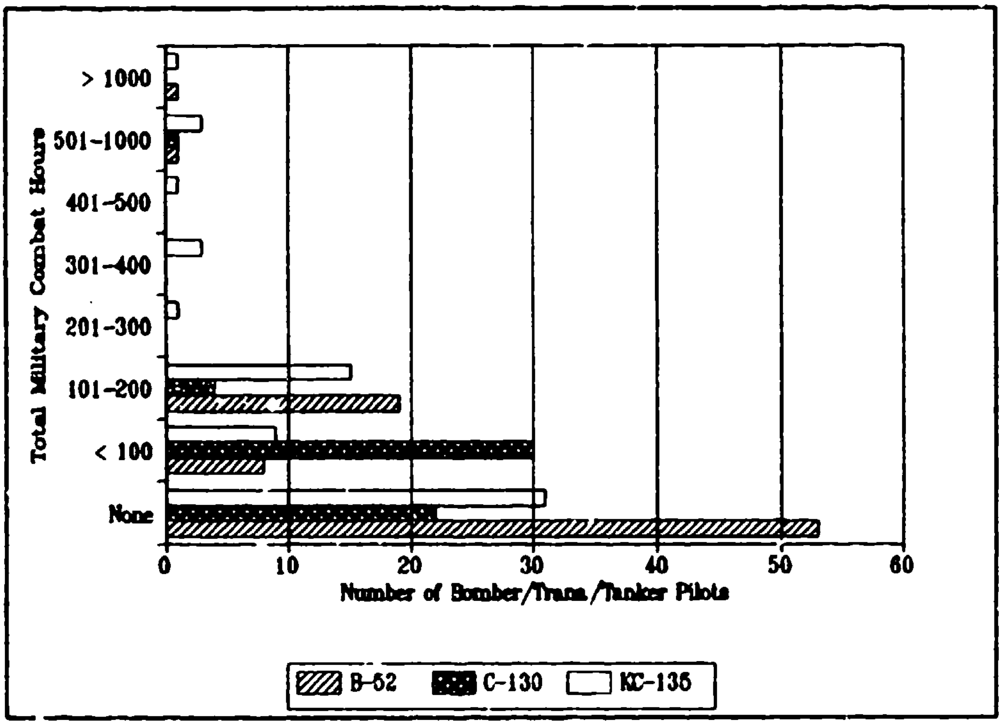

Figure 4-14. Total Military Combat Time of B-52, C-130, and KC-135 Respondents

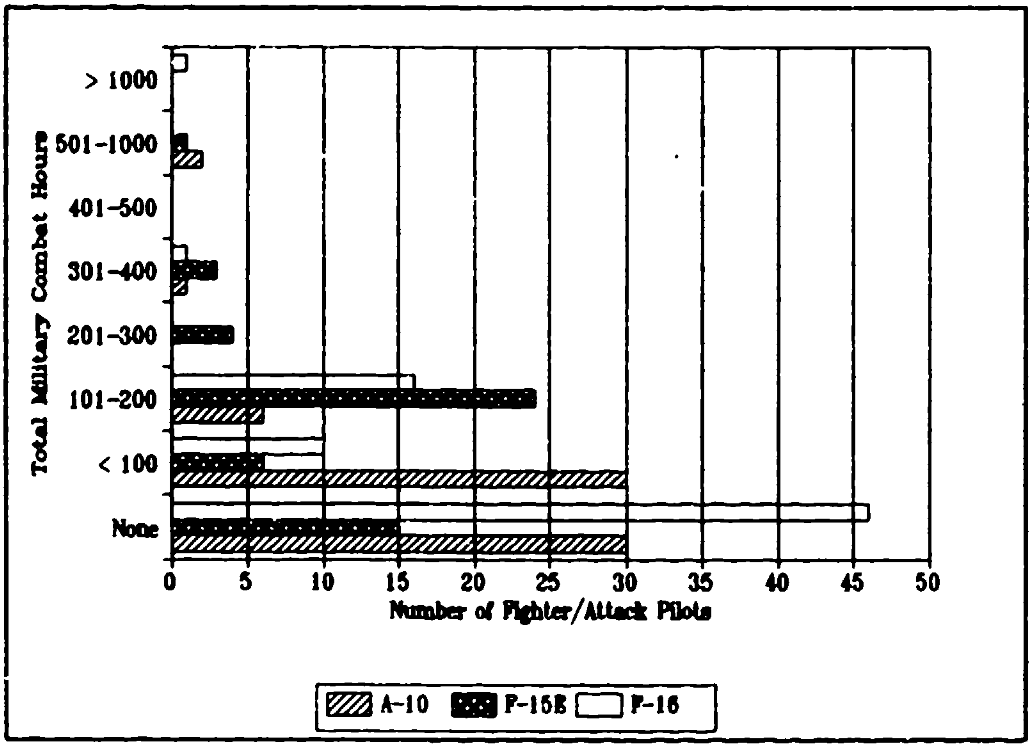

Figure 4-15. Total Military Combat Time of A-10, F-15E, and F-16 Respondents

group of Air Force aviators. This sample is probably more experienced than the average Air Force operational flying squadron. The high level of peacetime and wartime operational experience add credibility to the sample comments and findings of this study.

Analysis of Combat Mission Effectiveness Factors

The first objective of this study was to answer research question number one posed in Chapter I by quantitatively examining responses to questions 16 to 46 in the survey. As discussed in Chapter III, each question listed a specific mission effectiveness factor that might impact a combat mission. Respondents used a 5-point Likert scale to record their perception of how critical a factor was to effectively performing their mission. For each aircraft type, a mean response was calculated by summing all the responses to a particular question then dividing by the total number of respondents. This was accomplished using the SAS statistical analysis package. As discussed in Chapter III, the following scale was used by the researchers to categorize a particular mission effectiveness factor:

< 1.600	Always Critical to Mission Success
1.600 - 2.599	Almost Always Critical to Mission Success
2.600 - 3.599	Can be Critical to Mission Success
3.600 - 4.599	Almost Never Critical to Mission Success
> 4.600	Never Critical to Mission Success

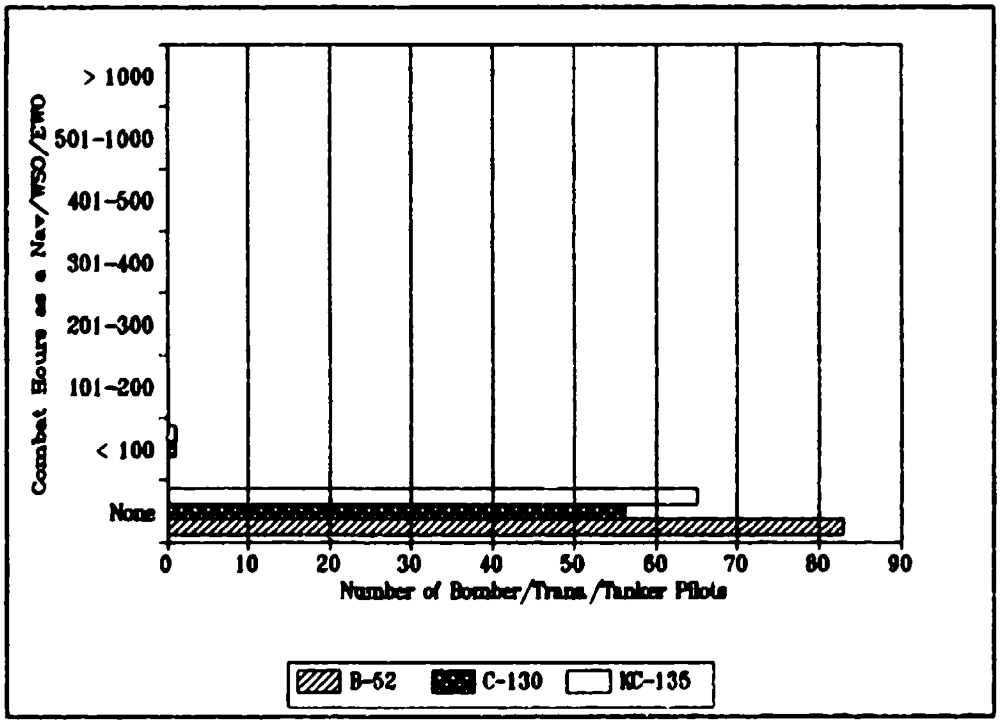

Figure 4-16. B-52, C-130, and KC-135 Respondents with Combat Experience as a Navigator/WSO/EWO

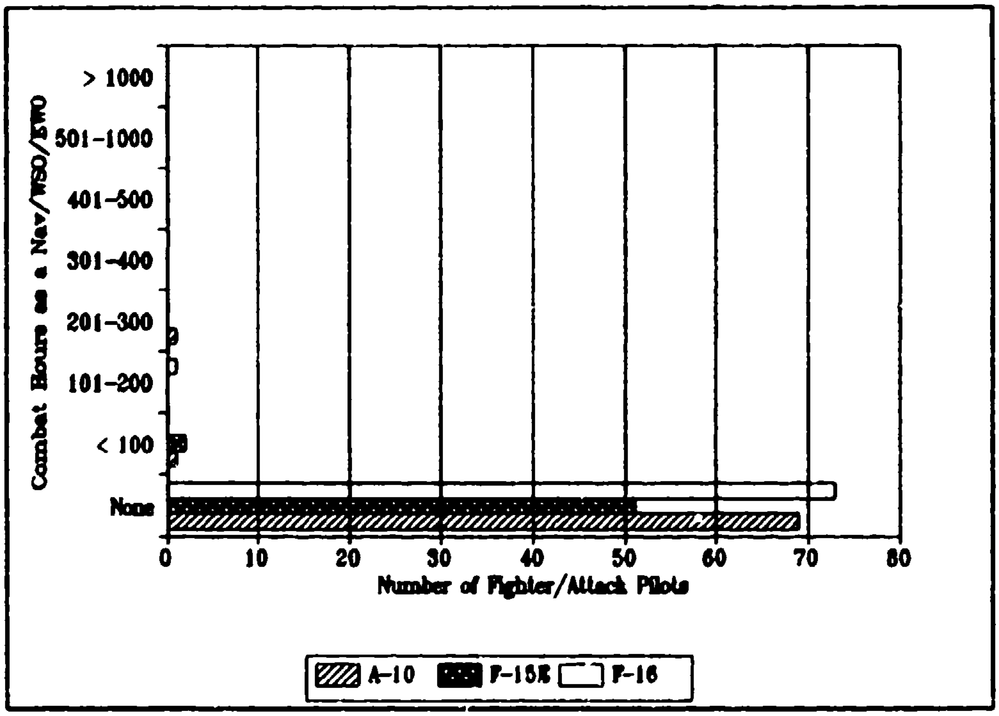

Figure 4-17. A-10, F-15E, and F-16 Respondents with Combat Experience as a Navigator/WSO/EWO

Listed below for each aircraft are the combat mission effectiveness factors rated as Always Critical to effective mission performance. The table includes the overall mean response and the standard deviation for each mission factor rated as always critical for each aircraft.

TABLE 4-1
ALWAYS CRITICAL MISSION EFFECTIVENESS
FACTORS BY AIRCRAFT

Aircraft	Mission Effectiveness Factor		Mean	Std Dev
A-10	1.	Target Acquisition	1.099	.3446
	2.	Munitions Employment	1.254	.6911
	3.	Situational Awareness	1.254	.5786
	4.	Threat Avoidance	1.507	.6734
B-52	1.	Threat Avoidance	1.361	.5314
	2.	Situational Awareness	1.374	.6573
	3.	Threat Detection	1.410	.6056
	4.	Crew Coordination	1.506	.6874
C-130	1.	Crew Coordination	1.246	.4343
	2.	Mission Planning	1.321	.5755
	3.	Situational Awareness	1.333	.6075
	4.	Threat Avoidance	1.439	.7324
F-15E	1.	Situational Awareness	1.189	.3950
	2.	Target Acquisition	1.358	.5914
	3.	Mission Planning	1.358	.5914
	4.	Munitions Employment	1.377	.6571
	5.	Threat Avoidance	1.453	.6066
	6.	Threat Detection	1.528	.6386
	7.	Monitoring On-Board Avionics & Weapons Systems	1.547	.6952
F-16	1.	Mission Planning	1.243	.6986
	2.	Target Acquisition	1.365	.7323
	3.	Situational Awareness	1.405	.7749
	4.	Munitions Employment	1.405	.8095
	5.	Threat Detection	1.541	.7251
	6.	Threat Avoidance	1.554	.7611
KC-135	No factors rated as critical			

Note the degree of commonality shared between aircraft performing different combat missions for the critical mission effectiveness factors. Situational awareness and threat avoidance are present in all but one of the aircraft. In addition, threat detection, mission planning, target acquisition, and munitions employment appear in three of the various aircraft. It is surprising that munitions employment did not appear in this list for the B-52. Only one factor (monitoring on-board avionics & weapons systems) appears just once in the entire list. Strikingly absent from the list are any factors rated as always critical by KC-135 pilots. Comparing the categories of always critical mission effectiveness factors to almost always critical mission effectiveness factors reveals many more factors in the "almost" category.

Following is a table for each aircraft of the combat mission factors rated as almost always critical to effective mission performance. Each aircraft has a separate table because of the large number of mission factors that were rated as almost always critical. Each table includes the mission effectiveness factor (ranked in order of most significant mean), its mean, and its standard deviation. A complete list of all the mission effectiveness factors for each aircraft with their computed means and standard deviations is included in Appendix D.

TABLE 4-2
A-10
ALMOST ALWAYS CRITICAL MISSION EFFECTIVENESS FACTORS

Mission Effectiveness Factor	Mean	Std Dev
1. Threat Detection	1.620	.7044
2. Visual Lookout	1.676	.8413
3. Aircraft Maneuvering (To avoid air and ground threats and no fly areas)	1.676	.8581
4. Mission Planning	1.916	.9373
5. Flight Safety	1.944	.9545
6. Formation Management	2.028	.8779
7. Visual Drop Capability	2.100	1.4461
8. Level of Aircrew Taskings	2.211	.8266
9. Terrain Avoidance/Following	2.211	1.0943
10. Ability to Fly in Adverse Weather/Low Inflight Visibility	2.229	.9195
11. Ability to Handle Inflight Emergencies	2.254	.9960
12. Low Level Navigation	2.268	.9096
13. Management of Time Over Target	2.366	.9598
14. Inflight, No-Notice Mission Changes	2.451	.9825
15. Monitoring On-Board Avionics & Weapon Systems	2.479	1.0122
16. Command & Control (Includes copying and decoding EAMS)	2.563	1.0520

TABLE 4-3
B-52
<u>ALMOST</u> ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor		Mean	Std Dev
1.	Munitions Employment	1.602	.7954
2.	Mission Planning	1.639	.8202
3.	Management of Time Over Target	1.663	.8157
4.	Low Level Navigation	1.735	.8422
5.	Flight Safety	1.747	.8673
6.	Ability to Fly in Adverse Weather/Low Inflight Visibility	1.771	.8600
7.	Aircraft Maneuvering (To avoid air and ground threats and no fly areas)	1.783	.7333
8.	Terrain Avoidance/Following	1.795	.7926
9.	Target Acquisition	1.795	.9848
10.	Command & Control (Includes copying and decoding EAMS)	1.819	.9518
11.	Night Low Level Navigation	1.843	.8335
12.	Night Operations	1.976	.8111
13.	Monitoring On-Board Avionics & Weapon Systems	1.988	.9172
14.	Ability to Handle Inflight Emergencies	2.133	.9470
15.	Level of Aircrew Taskings	2.157	.7884
16.	Crew Fatigue	2.205	.8801
17.	Aircrew Workload	2.446	.7691
18.	Visual Lookout	2.494	.9156
19.	Inflight, No-Notice Mission Changes	2.518	.9155
20.	Formation Management	2.566	.8292

TABLE 4-4
C-130
ALMOST ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor	Mean	Std Dev
1. Flight Safety	1.684	.8485
2. Management of Time Over Target	1.702	.7311
3. Aircraft Maneuvering (To avoid air and ground threats and no fly areas)	1.737	.8134
4. Terrain Avoidance/Following	1.754	.8718
5. Ability to Handle Inflight Emergencies	1.825	.8045
6. Low Level Navigation	1.860	.6928
7. Target Acquisition	1.946	1.3269
8. Visual Drop Capability	1.912	.8718
9. Visual Lookout	1.965	.8444
10. Level of Aircrew Taskings	2.000	.7319
11. Ability to Fly in Adverse Weather/Low Inflight Visibility	2.018	.7904
12. Night Low Level Navigation	2.053	.7658
13. Crew Fatigue	2.105	.7484
14. Aircrew Workload	2.140	.7662
15. Threat Detection	2.140	1.0254
16. Formation Management	2.158	.7971
17. Short-Unimproved Airfield Operations	2.281	.8610
18. Night Operations	2.316	.8693
19. Monitoring On-board Avionics & Weapon Systems	2.333	1.0579
20. Inflight, No-Notice Mission Changes	2.351	.8343
21. Ability to Handle Crew Member Incapacitation	2.404	.8631
22. Command & Control (Includes copying and decoding EAMS)	2.456	.7576

TABLE 4-5
F-15E
ALMOST ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor	Mean	Std Dev
1. Aircraft Maneuvering (To avoid air and ground threats and no fly areas)	1.604	.7163
2. Visual Lookout	1.679	.7009
3. Crew Coordination	1.755	.6767
4. Level of Aircrew Taskings	1.830	.8713
5. Night Operations	1.925	.7298
6. Terrain Avoidance/Following	2.038	.7835
7. Aircrew Workload	2.038	.8540
8. Flight Safety	2.038	.9600
9. Ability to Fly in Adverse Weather/Low Inflight Visibility	2.151	.8412
10. Management of Time Over Target	2.189	.9211
11. Night Low Level Navigation	2.208	.7168
12. Formation Management	2.302	.7490
13. Low Level Navigation	2.377	.7132
14. Inflight, No-Notice Mission Changes	2.434	.7969
15. Crew Fatigue	2.491	.7499

TABLE 4-6
F-16
ALMOST ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor	Mean	Std Dev
1. Visual Lookout	1.622	.8392
2. Aircraft Maneuvering (To avoid air and ground threats and no fly areas)	1.743	.8768
3. Monitoring On-Board Avionics & Weapon Systems	1.757	.8729
4. Flight Safety	1.757	1.0312
5. Level of Aircrew Taskings	1.919	.8236
6. Management of Time Over Target	2.135	.7994
7. Formation Management	2.162	.8605
8. Aircrew Workload	2.247	.9687
9. Ability to Handle Inflight Emergencies	2.257	.9517
10. Visual Drop Capability	2.365	.9731
11. Command & Control (Includes copying and decoding EAMS)	2.419	.7765
12. Terrain Avoidance/Following	2.425	.9707
13. Equipment Degradation During Mission	2.446	.8463
14. Ability to Fly in Adverse Weather/Low Inflight Visibility	2.514	.7261
15. Crew Fatigue	2.541	.8788
16. Inflight, No-Notice Mission Changes	2.554	.7050
17. Low Level Navigation	2.595	.7007

TABLE 4-7
KC-135
ALMOST ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor	Mean	Std Dev
1. Flight Safety	1.758	.8424
2. Situational Awareness	1.909	.8544
3. Ability to Fly in Adverse Weather/Low Inflight Visibility	2.046	.9088
4. Crew Coordination	2.061	.8750
5. Mission Planning	2.212	.9201
6. Command & Control (Includes copying and decoding EAMS)	2.397	.9595
7. Ability to Handle Inflight Emergencies	2.379	.9075
8. Station Keeping	2.385	.9133
9. Formation Management	2.431	.7494
10. Inflight, No-Notice Mission Changes	2.546	.7271
11. Aircrew Workload	2.591	.8767
12. Threat Avoidance	2.591	1.0521

An examination of the six tables above reveals the commonality of the top five factors for each aircraft type. Flight safety is listed for five of the six aircraft as one of the top five mission factors considered as almost always critical to mission success. For the aircraft (F-15E) that did not consider it in the top five, it was listed as number eight. Aircraft maneuvering appeared in the top five for four of the aircraft. It appeared as number seven in the B-52 table and it was not included in the KC-135 table. Mission planning and visual lookout were both listed three times. Mission planning was listed for those aircraft that had previously not included it in the always critical mission effectiveness factor list. Visual lookout was in the top five list for the fighter aircraft and was number nine for the C-130, number eighteen for the B-52, and was not on the list for the KC-135. Munitions employment for the B-52, with a mean of 1.602, was the top factor in the almost always critical table.

Targets of opportunity and high speed airdrop were two factors that did not appear in any of the six aircraft tables as always critical or almost always critical to successful mission accomplishment. In addition, equipment degradation during the mission, ability to handle crew member incapacitation, station keeping, and short-unimproved airfield operations were factors that appeared only one time in any of the almost always critical factor tables.

It is also useful to compare the standard deviations between the factors in the always critical and the almost always critical tables. In general, the standard deviations in the always critical table of mission effectiveness factors are smaller than the ones in the almost always critical table. There is not a single factor in the always critical table with a standard deviation over 1.0; most are under .75. This small standard deviation indicates that there is closer agreement among the pilots on the always critical factors than on the almost always critical factors.

At the end of the list of mission effectiveness factors in the survey, the respondents were invited to write in any additional factors they believed to be always critical to mission success but were not included in the survey. A table for each aircraft of the write-in factors follows.

TABLE 4-8
A-10
SURVEY COMMENTS: ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor
1. Copy FAC brief/Understand Tactical situation to include target/threat/friendly locations.
2. Bombs/bullets/mavericks on target.
3. Weapons availability.
4. Communications.
5. SEAD.
6. Adaption to night operations in a day VFR fighter.
7. Deconfliction of fighters in/out of target.
8. Threat suppression available at all times.
9. ABCCC communications and updates.
10. Crew rest (i.e. capability of getting it during MOB missile attacks).
11. Experience.
12. Mission qualification.
13. Aggressiveness.
14. Working with no prebrief & very little communications with other flights.
15. Ability to communicate with a FAC.
16. Good, timely, intelligence; especially raw data from <u>all</u> sources.
17. Accounting for actual battle damage to the target after the attack.
18. Precision guided weapons are key!!
19. Ground target identification at night requires high IR resolution.
20. Communications - UHF/VHF/FM secure voice.
21. Good communication.
22. Good intel (at least decent).
23. Realistic training.
24. Assignment of targets (type-location-threats in location of tgt.
25. Aircrew training.
26. Good Intelligence feedback.
27. Force packaging.
28. Proper A.C./munitions for the task.
29. Navigation.
30. Near real time cockpit info displays.
31. Clear radio communications.

TABLE 4-9
B-52
SURVEY COMMENTS: ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor
1. Air support packages.
2. Crew experience level.
3. Inflight air refueling capability.
4. Night vision goggles.
5. Intra-plane communications (secure, or Undetected).
6. Intra Theater communications (other planes to us, ground to us).
7. Previous joint ops experience.
8. Experience as an integral crew.
9. Training like you will fight.
10. Inter-Unit communication.
11. Strike package coordination.
12. Proficiency of aircrew.
13. Proficiency of planners.
14. Airborne Comm plans.
15. Intra-formation communications.
16. Emission Control plans.
17. High Altitude Delivery Tactics.
18. Intelligence (up to date) information.
19. Target compatibility (right weapon system for target).
20. Weapon system survivability/redundancy.
21. Coordination of all players, i.e.: mission package
22. Effective communication with ABCCC & package.
23. Nutrition.
24. Crew rest/living conditions.
25. Air refueling support/capability.
26. Accuracy of bombing-both nuclear & conventional with unguided weapons.
27. Ability to program guided missiles for air launch (nuc mission).
28. Ability to correctly & effectively employ coordinated ECM & aerial defensive gunnery for bomber defense.
29. Current intelligence.
30. Joint service coordination.
31. Aerial refueling.
32. Staff involvement or failure of staff to provide adequate products to mission plan with, provide proper coordination with other units in a high density, aircraft, environment.
33. Ability to integrate with AWACS (same as 34).
34. Support packages (e.g. SEAD, CAP) for strikes.

TABLE 4-10
C-130
SURVEY COMMENTS: ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor
1. Morale.
2. Crew proficiency.
3. Coordination with the user - i.e. the people being airdropped or being resupplied.
4. Decontamination of chemicals on med evac patients.
5. Systems knowledge.
6. Field repair capability.
7. Inflight refueling capability.
8. User support.
9. Timely target intell.
10. Secure voice (that works).
11. Crew morale & welfare.
12. Accurate intel updates.
13. Dissemination and compliance with airspace control orders.
14. Communication plan: Chattermark, Encode, Decode.
15. Theater special instructions - knowledge and compliance of.
16. High accuracy on board navigation system.
17. Defensive capability.

TABLE 4-11
F-15E
SURVEY COMMENTS: ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor
1. Target study.
2. Threat management (SA-2 on the way or AAA all around - where do you look?).
3. Intelligence support.
4. Munition availability.
5. Target photos.
6. Mensurated coordinates (for TGT & updates).
7. Go/No-Go pills to get good crew rest and stay alert.
8. Approval through AWACS on targets of opportunity.
9. Experience.
10. Knowledge of systems/aircraft/adversaries.
11. Visual illusion/disorientation.
12. A/A capability.
13. Comm Jam environment.
14. RWR capability.
15. Jamming capability.
16. Expendables capability.
17. System WPN delivery accuracy.
18. System performance feedback (can be critical).
19. Air refueling.
20. Proper training.
21. Systems knowledge.
22. Intel information (part of mission planning).
23. Defensive systems (i.e. chaff, flares, ICS, etc.).
24. Decent intelligence.

TABLE 4-12
F-16
SURVEY COMMENTS: ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor	
1.	Orders of battle to include: electronic (EOB); Air (AOB); Ground (GOB), threats.
2.	Situational awareness.
3.	Threat awareness.
4.	Area of Operation Intelligence (photos of TGT, Threats in area etc...)
5.	Maintenance.
6.	Communication (Intra Flt).
7.	Pilot competence (training).
8.	Intel.
9.	Morale.
10.	Friendly asset deconfliction to prevent frataracide.
11.	The best capable pilot in the most demanding position!
12.	Enough training to be competent at every situation that arises.
13.	The best technology available, and then get it in the jet.
14.	Force composition (size & type of A/C in package).
15.	Dedicated SEAD assets.
16.	Air superiority.
17.	Timely & accurate Intel.
18.	Survival - #1
19.	Mutual support of WG/Flight leads.
20.	Mutual support.
21.	System accuracy.
22.	Intell (where are the threats?)
23.	Force composition.
24.	Electronic jamming.
25.	Medium altitude ingress.
26.	Air refueling.
27.	Threat suppression.
28.	Ability to fly above weather and hit targets on ground.
29.	Ability to go supersonic in Mil power.
30.	Accurate Intelligence for mission planning.
31.	Weapons availability (proper for target).
33.	Strong inflight leadership.
34.	Flight (& self) discipline.
35.	Judgement.
36.	Basic airmanship.

TABLE 4-13
KC-135
SURVEY COMMENTS: ALWAYS CRITICAL MISSION
EFFECTIVENESS FACTORS

Mission Effectiveness Factor
1. Good maintenance support.
2. Sortie scheduling/circadian rhythm.
3. Severe weather avoidance.
4. Secure communications capability.
5. Accurate navigation.
6. Traffic deconfliction.
7. Protection from potential hostiles.
8. Rapid offload to numerous receivers.
9. Air refueling control time keeping.
10. Plays the part of "Deputy Mission Commander."
11. Rendezvous during Air Refueling (AR) & Navigation during AR.
12. Comm discipline.
13. Up to date intelligence on the surface to air threats!
14. A more accurate means of navigation with point position update capability.
15. Fuel management.
16. Procedures knowledge.
17. Flexibility
18. Clearly defined mission (otherwise mission planning is useless).
19. Planes that work (at least vital equipment) = effective maintenance.
20. Job knowledge & proficiency - how to fly plane, & rules, procedures, techniques that apply to it.
21. Leadership ability on crew airplanes.
22. Discipline to continue to job when going gets tough.
23. Accurate Intel.

A casual glance at the six tables above reveals there are numerous additional mission effectiveness factors that individual pilots consider as always critical to mission success. Some of the factors listed above are not much different than those already included in the survey. For example, adaption to night operations in a day VFR fighter, mentioned above, and night operations, included in the survey, both describe the significance of operations at night on the ability of pilots to perform their missions.

If a statistically significant sample of pilots of the various aircraft were asked to rate these additional factors on an appropriate scale, it is likely that many would not be considered as always critical to mission effectiveness. However, several of the factors that appear in all of the aircraft tables and appear more than once in any one table, such as timely and accurate target intelligence, communications, experience, and proper training would have a high probability of being rated as always critical by a particular pilot group.

NAVCRIT and REQ Data Analysis

This portion of the chapter will be devoted to analyzing the data received concerning the measures of NAVCRIT and REQ. Definitions of these two measures have been given in Chapter III. Each measure will be discussed separately. The discussion will consist of a presentation of frequency distributions by aircraft of NAVCRIT and REQ scores, the results of utilizing stepwise regression to predict NAVCRIT and REQ scores, and finally, a comparison by aircraft of NAVCRIT and REQ mean scores.

The method of deciding what survey items would make up the measures of NAVCRIT and REQ was discussed in Chapter III. The discussion stated two tests for internal validity would be used in determining NAVCRIT and REQ--Cronbach's

Alpha correlation and principal component analysis. These two tests were performed utilizing the SAS statistical computer package. A copy of the computer program used in this research project is in Appendix C.

Principal component analysis proved itself a great aid in reducing the number of survey items used in defining NAVCRIT and REQ. Initially, NAVCRIT and REQ were made up of twelve and six items, respectively. After using the SAS statistical computer package, the survey items making up NAVCRIT were reduced to eight and one item was eliminated from REQ. This analysis permitted the researchers to utilize the minimum number of survey questions in determining REQ and NAVCRIT. Principal component analysis showed the eliminated items were measuring factors other than those of NAVCRIT and REQ.

The results of the Cronbach's Alpha correlation for the eight NAVCRIT and five REQ items are shown in Tables 4-14 and 4-15:

TABLE 4-14
RELIABILITY TEST OF NAVCRIT USING CRONBACH'S ALPHA

Correlation Analysis
Cronbach Coefficient Alpha
for RAW variables : 0.918215
for STANDARDIZED variables: 0.919131

	Raw Variables		Std. Variables	
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha
Q47	0.799032	0.902176	0.789988	0.903741
Q50	0.775408	0.904887	0.765409	0.905765
Q51	0.670546	0.912133	0.664989	0.913882
Q57	0.732515	0.907850	0.736255	0.908147
Q58	0.840773	0.898442	0.839056	0.899657
Q62	0.629253	0.915194	0.634673	0.916286
Q63	0.572388	0.918989	0.577091	0.920791
Q73	0.843375	0.898398	0.845753	0.899095

TABLE 4-15
RELIABILITY TEST OF REQ USING CHRONBACH'S ALPHA

Correlation Analysis
Cronbach Coefficient Alpha
for RAW variables : 0.873400
for STANDARDIZED variables: 0.880837

	Raw Variables		Std. Variables	
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha
Q48	0.756235	0.832576	0.738867	0.849532
Q53	0.649007	0.861139	0.659267	0.868171
Q54	0.727900	0.849188	0.718633	0.854334
Q66	0.711548	0.844347	0.712784	0.855713
Q67	0.727210	0.843785	0.743171	0.848505

These two figures show a very high internal reliability of the NAVCRIT and REQ measures. A Cronbach's Alpha of approximate 0.9 points to a high measure of internal consistency for NAVCRIT and REQ (39:214-215).

Figures 4-18 through 4-23 graphically present each aircraft's frequency distribution of NAVCRIT scores. The NAVCRIT score can be from eight to forty. The overall score is determined by a respondent's answers to the eight questions that make up the NAVCRIT measure. If the individual selects the lowest scoring answers (one for each question), the overall NAVCRIT score will be eight. Conversely, if the same individual selects the highest score (five for each question), a score of forty on the NAVCRIT measure will result. A mix of scores on the eight questions will produce a NAVCRIT score greater than eight, but lower than forty.

Not surprisingly, the frequency distributions of NAVCRIT scores appear significantly different for each aircraft type. The B-52/F-15E pilots' NAVCRIT scores were at the upper end of the NAVCRIT scale. For example, 52.2 percent of F-15E responses and 51.3 percent of B-52 responses possess a NAVCRIT score of 37 or higher. The A-10 and F-16 pilots scored the lowest on the NAVCRIT scale. Over 60 percent of the A-10 pilots surveyed and 67.2 percent of F-16 respondents had NAVCRIT scores of 19 or lower. Also of note were the low scores of these four aircraft types.

The A-10 and F-16 distributions each included two pilots who scored an eight on NAVCRIT. In contrast, the low NAVCRIT score for the B-52 was 25 and for the F-15E it was 15.

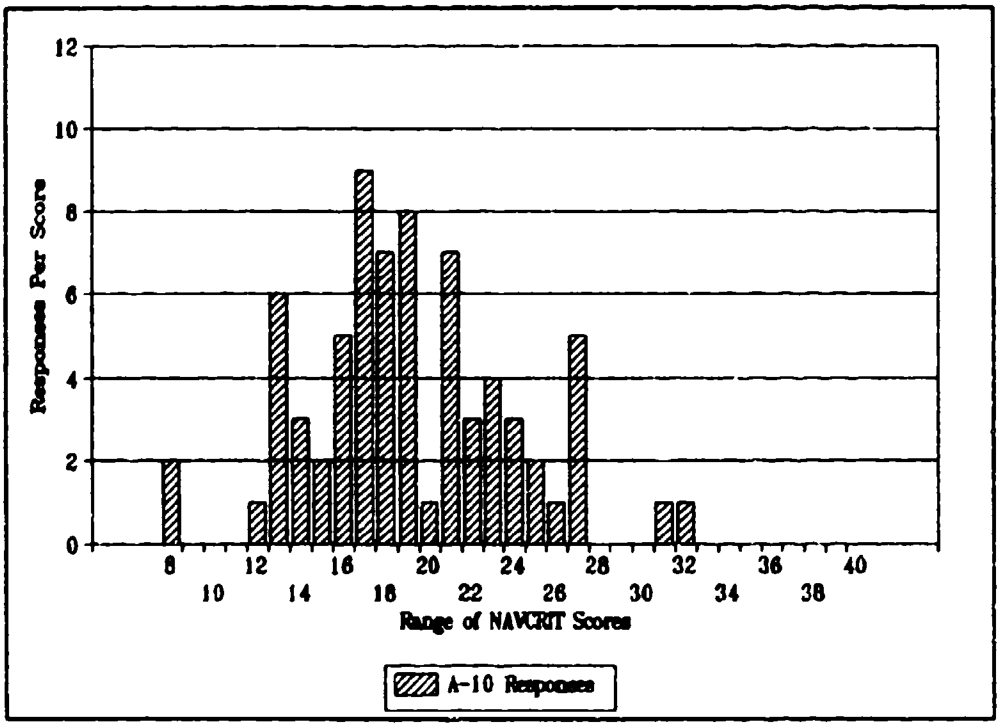

Figure 4-18. NAVCRIT Frequency Distribution, A-10 Pilots

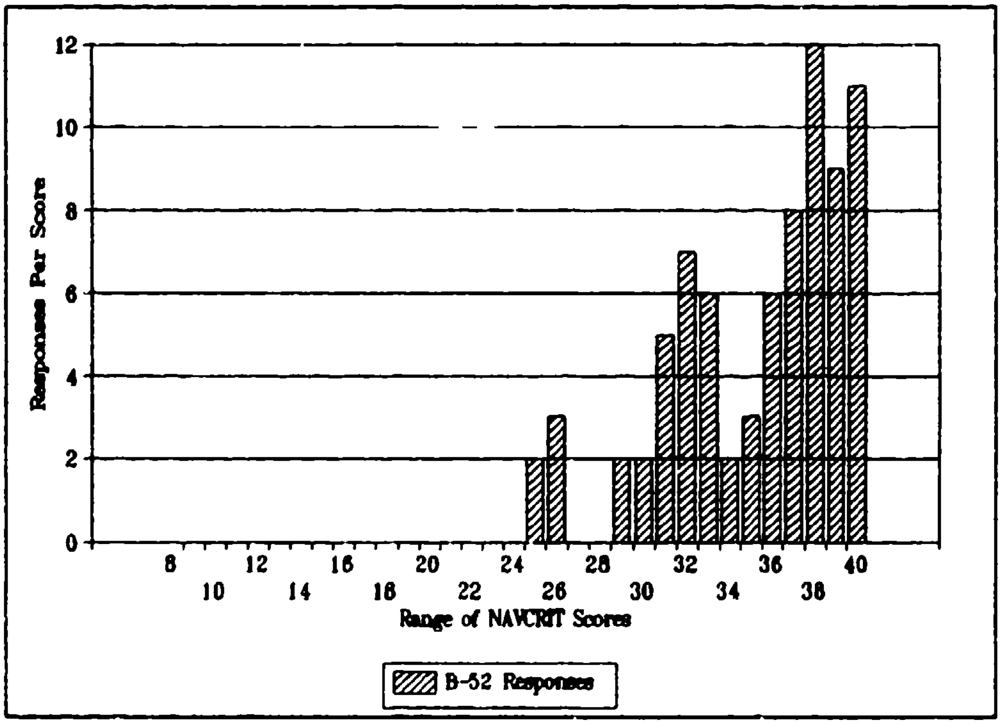

Figure 4-19. NAVCRIT Frequency Distribution, B-52 Pilots

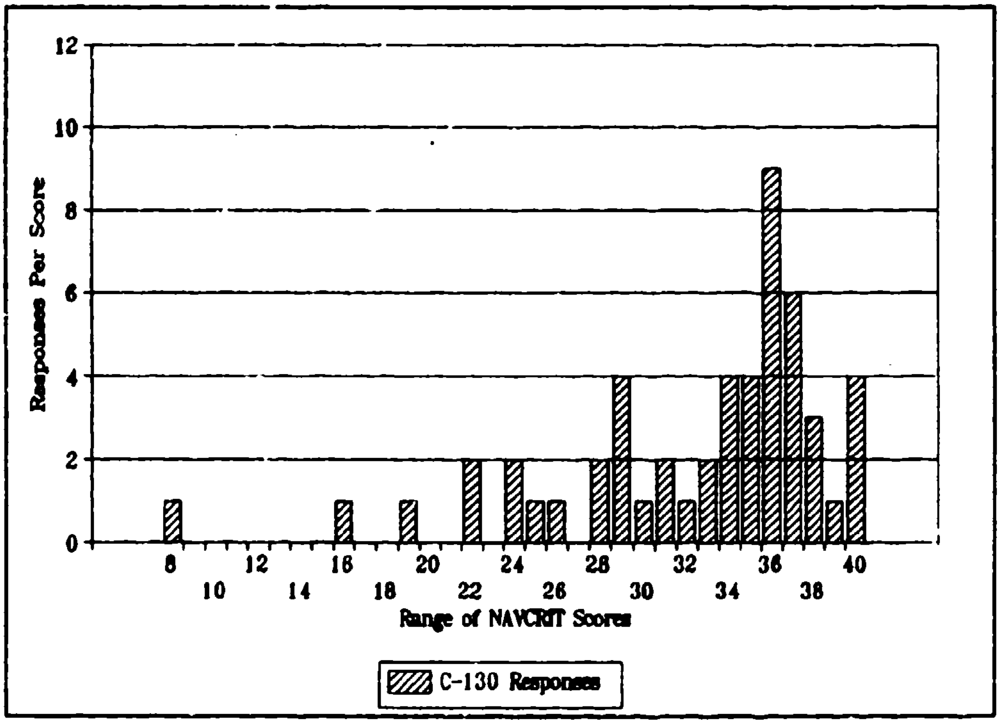

Figure 4-20. NAVCRIT Frequency Distribution, C-130 Pilots

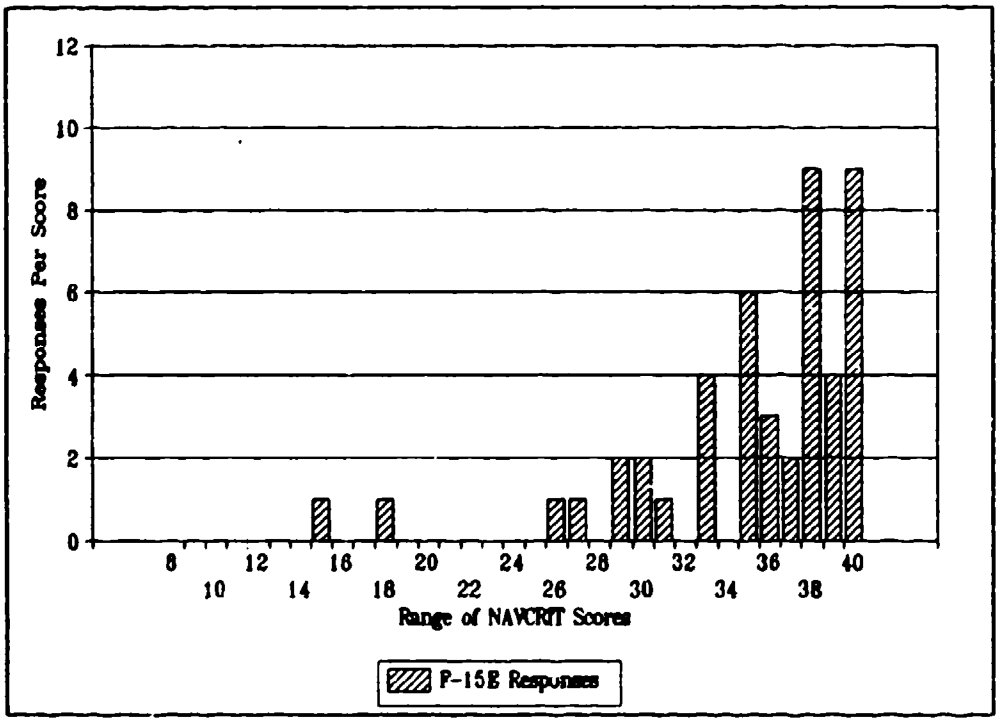

Figure 4-21. NAVCRIT Frequency Distribution, F-15E Pilots

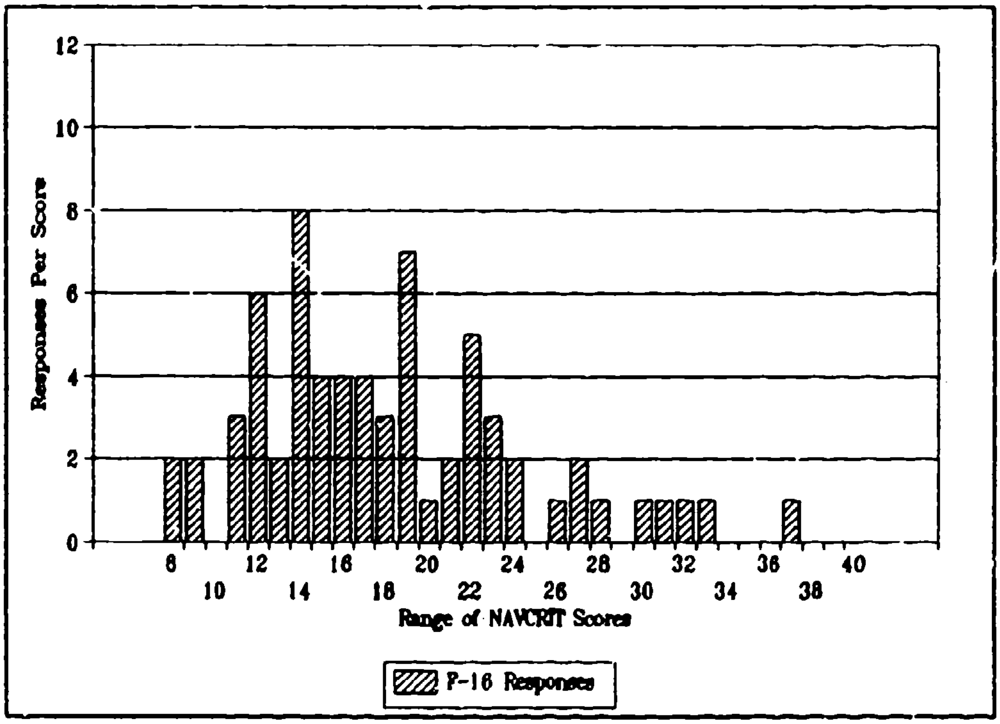

Figure 4-22. NAVCRIT Frequency Distribution, F-16 Pilots

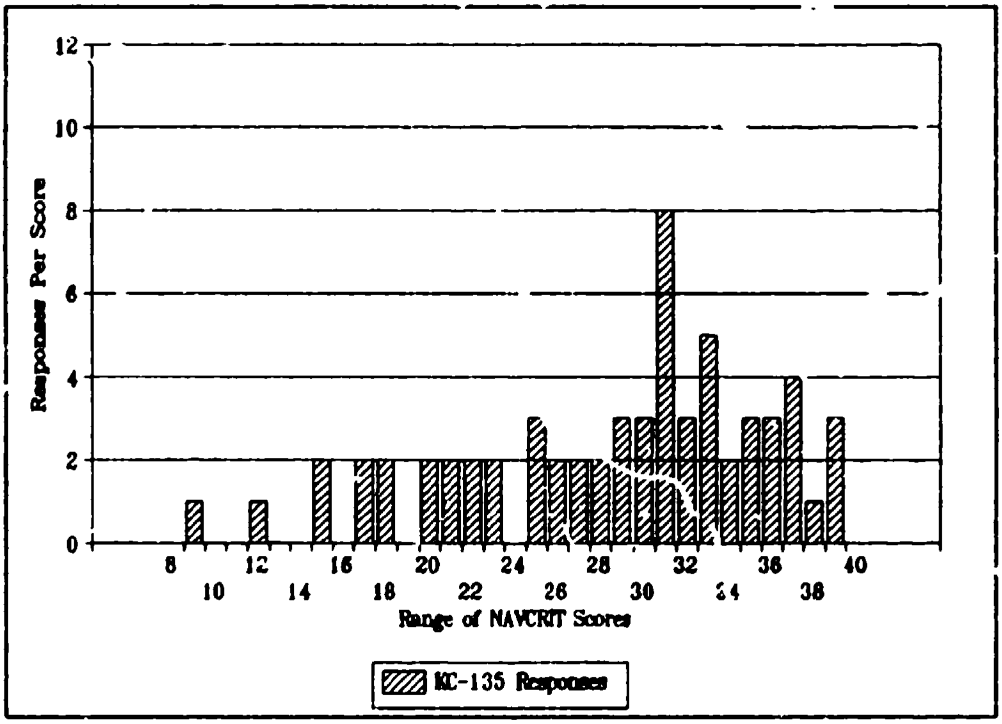

Figure 4-23. NAVCRIT Frequency Distribution, KC-135 Pilots

The C-130 and KC-135 NAVCRIT scores were not as high as the B-52/F-15E scores, but were significantly higher than the A-10/F-16 scores. Forty-four percent of all C-130 responaents and 17.4 percent of KC-135 surveyed pilots had NAVCRIT scores of 36 or higher. The C-130 frequency distribution low score was eight and the KC-135 low score was nine.

The next logical step in the research process was to determine what demographic factors accurately predicted NAVCRIT scores. Table 4-16 summarizes the results of a stepwise regression procedure that employed the demographic factors mentioned earlier in this chapter as predictors of NAVCRIT.

TABLE 4-16
RESULTS OF NAVCRIT STEPWISE REGRESSION USING SAMPLE DEMOGRAPHICS AS PREDICTORS

SURVEY DEMOGRAPHIC QUESTION	PARAMETER ESTIMATE	MODEL R^2	F	PROB > F
INTERCEPT	49.17639465		1204.97	[illegible]1
Q1 *	-0.68972801	.0201	10.83	.0[illegible]1
Q4 **	-1.96467845	.0316	6.42	.0117
Q6 ***	-13.97474110	.4704	305.19	.0001

* Q1: What aircraft do you currently fly?
** Q4: Prior to being qualified in the aircraft you selected in question 1, were you qualified to fly in any other operational, NOT trainer, aircraft?
*** Q6: Have you ever flown an airplane that included a Navigator/WSO/EWO as part of the crew?

The results of the stepwise regression were not conclusive nor encouraging in the search of NAVCRIT predictor model. The R^2 of .4704 means that only 47.04

percent of the variation of NAVCRIT scores is accounted for by the three demographics of type of aircraft currently flown, previous aircraft flown, and having ever flown with a Navigator/WSO/EWO (34:520).

Despite the fact that a reliable regression model was not found, a significant relationship still exists between the three demographic variables and NAVCRIT. This relationship should not be ignored. These relationships may help to explain the low NAVCRIT scores of the A-10 and F-16 respondents. Survey Question 6, due to its high R^2 contribution, appears to be the most significant factor in the stepwise regression model in Table 4-16. The survey data reveals that most F-16 and A-10 pilots have never flown with a Navigator/WSO/EWO. Figure 4-24 illustrates the number of A-10 and F-16 who have never flown with a navigator/WSO/EWO. The lack of ever flying with a navigator may have contributed to the A-10 and F-16 pilots' low NAVCRIT scores.

Next the researchers performed a stepwise regression on the sample database by aircraft type to discover a NAVCRIT predictor model. This regression operation yielded no useable results. For example, no significant demographic factors yielded a model for any of the six aircraft. The KC-135 had no factor in the stepwise regression model to predict NAVCRIT. The R^2 of any individual aircraft model was no higher than .05. Therefore, the "best" model the researchers have in predicting NAVCRIT is the model

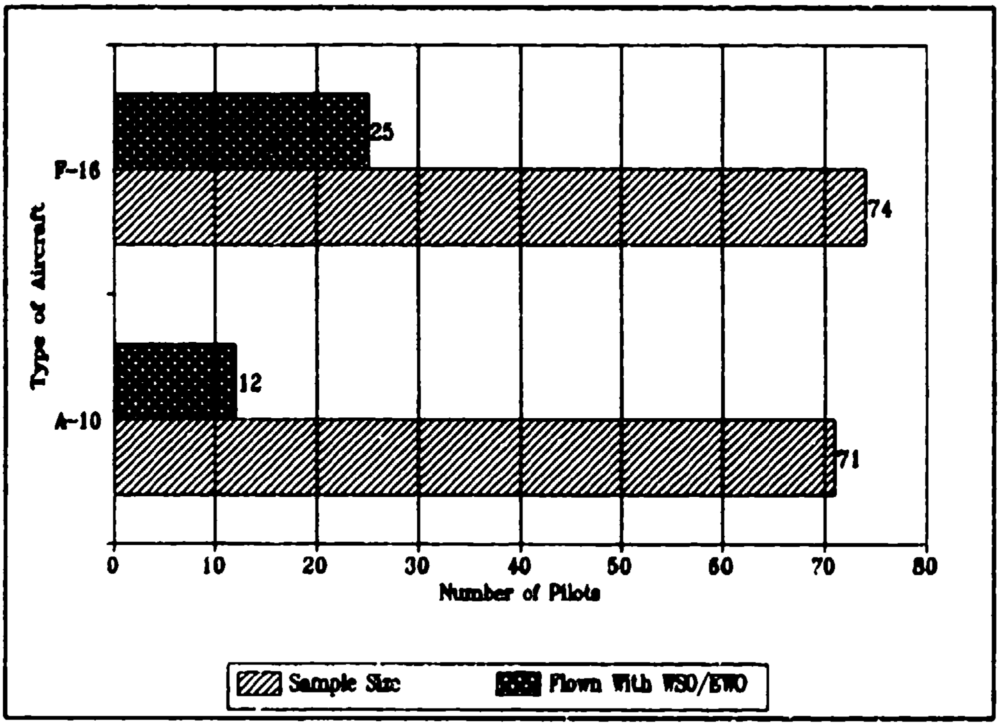

Figure 4-24. A-10 and F-16 Respondents' Flying Experience with a Navigator/WSO/EWO

illustrated in Table 4-16. This model is not one that would be recommended for use, but it is a model that provides links to certain demographic relationships and NAVCRIT.

The final look at the NAVCRIT data concerned the concept of degrees of NAVCRIT. The researchers were looking for the amount of need for a navigator/WSO/EWO on each of the six aircraft studied. In other words, a navigator/WSO/EWO may be more valuable in certain aircraft in the role of enhancing the mission critical factor accomplishment. The authors of this study chose to use the Bonferroni procedure for multiple comparisons to explore the research possibility. The Bonferroni procedure is very simple and assures the level of significance will be at least 95 percent confident (34:864). Table 4-17 provides the results of the Bonferroni procedure:

TABLE 4-17
RESULTS OF MEANS COMPARISON BY AIRCRAFT OF NAVCRIT
(BONFERRONI T TESTS)

AIRCRAFT COMPARISON	DIFFERENCE BETWEEN MEANS	
B-52 - F-15E	0.3432	
B-52 - C-130	3.1048	***
B-52 - KC-135	6.5705	***
B-52 - A-10	16.1515	***
B-52 - F-16	17.2145	***
F-15E - B-52	-0.3432	
F-15E - C-130	2.7616	
F-15E - KC-135	6.2273	***
F-15E - A-10	15.8083	***
F-15E - F-16	16.8712	***
C-130 - B-52	-3.1048	***
C-130 - F-15E	-2.7616	
C-130 - KC-135	3.4657	***
C-130 - A-10	13.0467	***
C-130 - F-16	14.1096	***
KC-135 - B-52	-6.5705	***
KC-135 - F-15E	-6.2273	***
KC-135 - C-130	-3.4657	***
KC-135 - A-10	9.5810	***
KC-135 - F-16	10.6439	***
A-10 - B-52	-16.1515	***
A-10 - F-15E	-15.8083	***
A-10 - C-130	-13.0467	***
A-10 - KC-135	-9.5810	***
A-10 - F-16	1.0630	
F-16 - B-52	-17.2145	***
F-16 - F-15E	-16.8712	***
F-16 - C-130	-14.1096	***
F-16 - KC-135	-10.6439	***
F-16 - A-10	-1.0630	

*** Comparisons significant at the 0.95 confidence level
Alpha= .05, degrees of freedom= 361, MSE= 32.63414
Critical Value of T= 2.95487

Table 4-17 clearly shows significant differences in mean comparisons of the six aircraft types. The degree that a navigator/WSO/EWO contributes to the critical mission effectiveness factors is shown in Table 4-18:

TABLE 4-18
SUMMARY OF NAVCRIT MEANS BY AIRCRAFT OF THE PERCEIVED NEED FOR A NAVIGATOR/WSO/EWO FOR SUCCESSFUL ACCOMPLISHMENT OF CRITICAL MISSION EFFECTIVENESS FACTORS

DEGREE OF NEED FOR A NAVIGATOR/WSO/EWO	AIRCRAFT
I (HIGHEST)	B-52/F-15E
II	F-15E/C-130
III	KC-135
IV (LOWEST)	A-10/F-16

The degree of need illustrated in Table 4-18 represents only the six aircraft studied. If all USAF aircraft types were examined there could be many more degrees of need than illustrated here. This table shows that there is a significant difference in the NAVCRIT means of the six aircraft. Of note is the F-15E--it appears in Degree I and Degree II. Table 4-17 explains why the F-15E appears in two categories. When the B-52 is compared to the other five aircraft, only the F-15E represents a non-significant difference. When the F-15E is compared to the other five aircraft, all but the B-52 and C-130 are significant mean differences. These non-significant mean differences occur because the F-15E mean falls between the B-52 and C-130 means and is not significantly different from either aircraft's mean. The B-52 possesses the highest NAVCRIT mean and is significantly higher than the C-130's.

The same procedures were followed for the analysis of REQ. Figures 4-25 through 4-30 show the frequency distributions of REQ scores for each surveyed aircraft type. The possible range of REQ scores is five to twenty-five. This range is based on the five questions that make up REQ.

The B-52, F-15E, and C-130 possessed very high scoring REQ distributions. For example, 68.1 percent of surveyed B-52 pilots, 77.3 percent of F-15E pilots, and 64.9 percent of C-130 respondents have REQ scores greater than 21. The low score for each of these sampled aircraft is 15 for the B-52, five for the C-130, and eight for the F-15E.

In contrast, the A-10 and F-16 had low scoring distributions. Over 61 percent of sampled A-10 pilots and over 64 percent of the F-16 pilots surveyed had REQ scores less than 20. Both distributions had low scores of five.

The KC-135 represented a middle ground in REQ scoring. The low score was eight. Over 50 percent of the KC-135 sample scored between 18 and 22 inclusive. The KC-135 sample did not possess the high number of respondents in the over 21 range similar to the B-52/F-15E/C-130 scores. It also did not possess the low distribution similar to the A-10/F-16 distributions.

Stepwise regression was also performed on REQ utilizing the same demographic predictor variables. Table 4-19 provides the results:

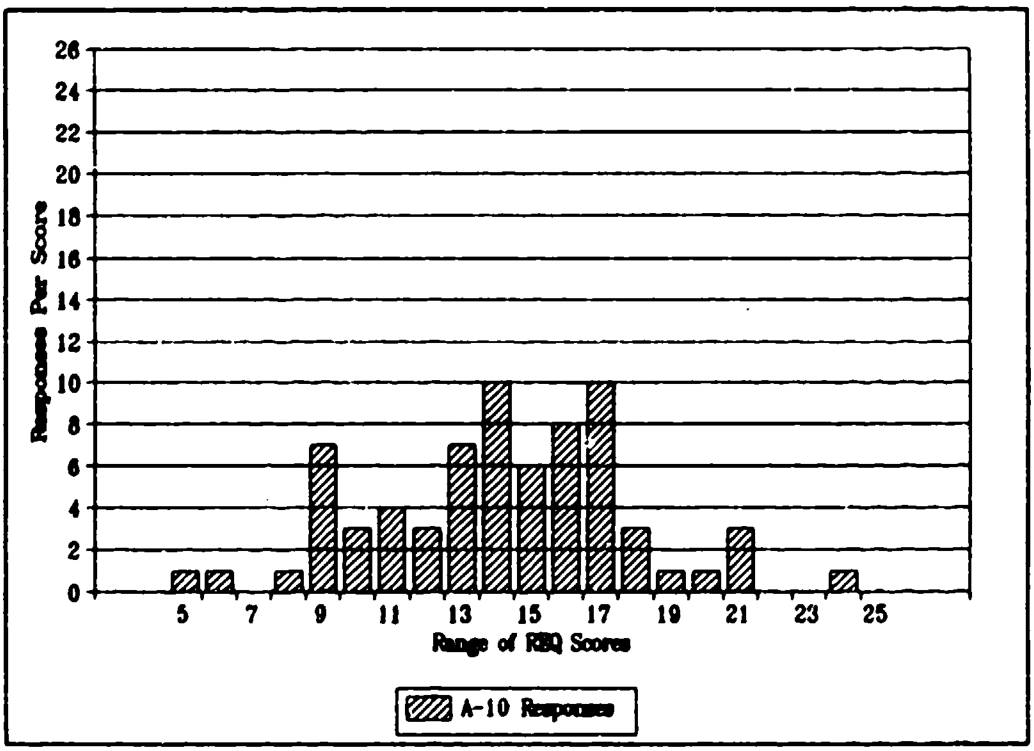

Figure 4-25. REQ Frequency Distribution, A-10 Pilots

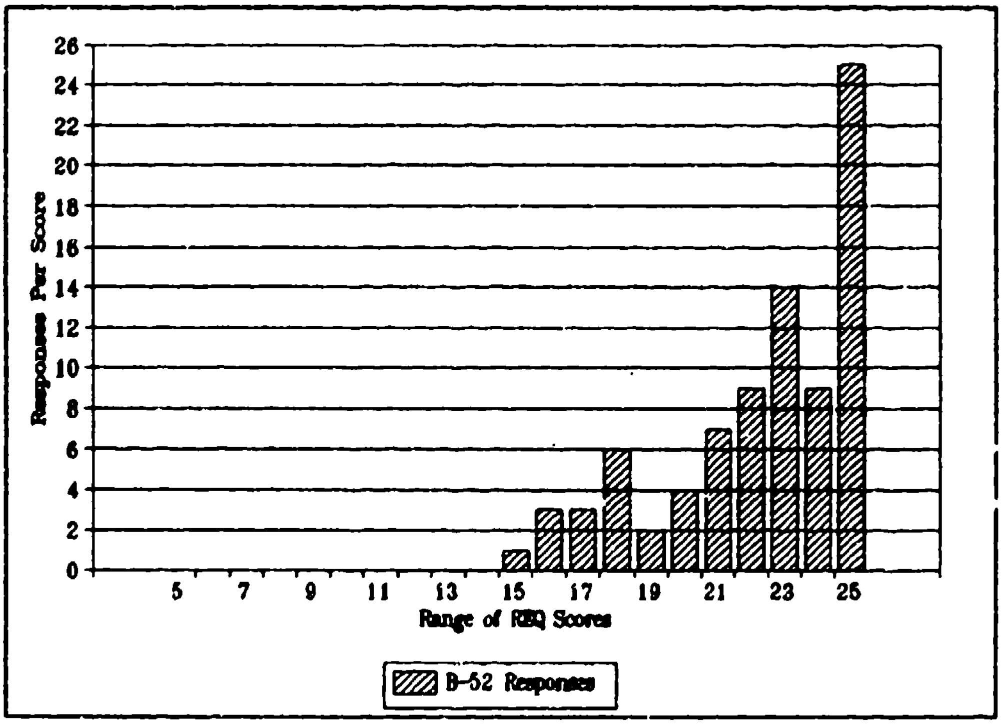

Figure 4-26. REQ Frequency Distribution, B-52 Pilots

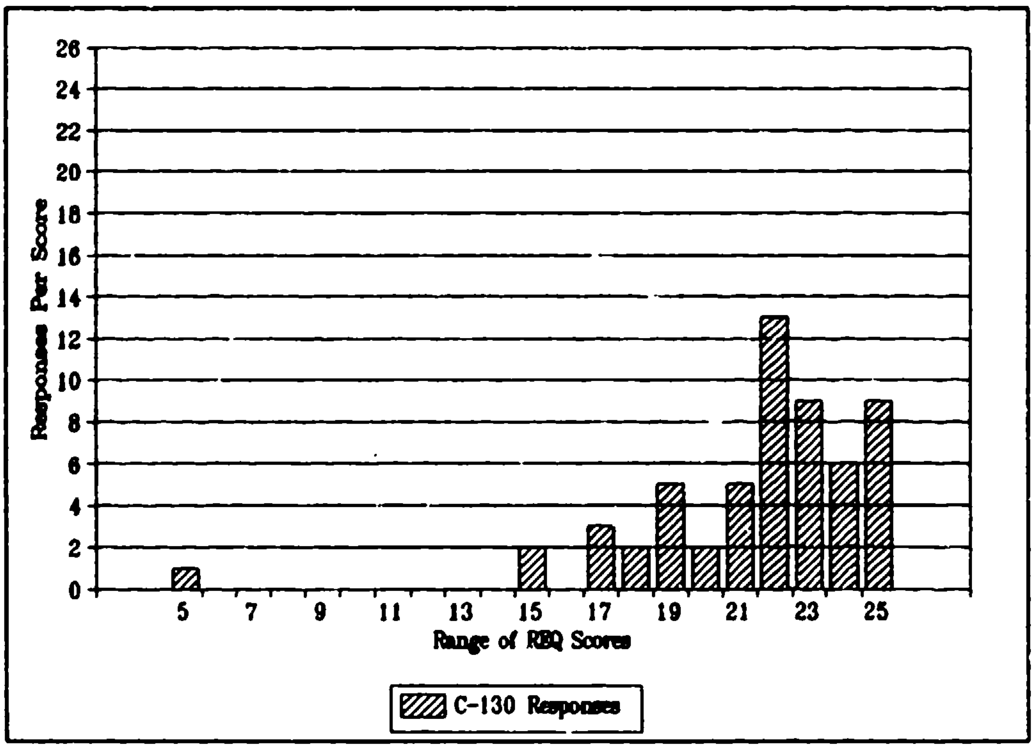

Figure 4-27. REQ Frequency Distribution, C-130 Pilots

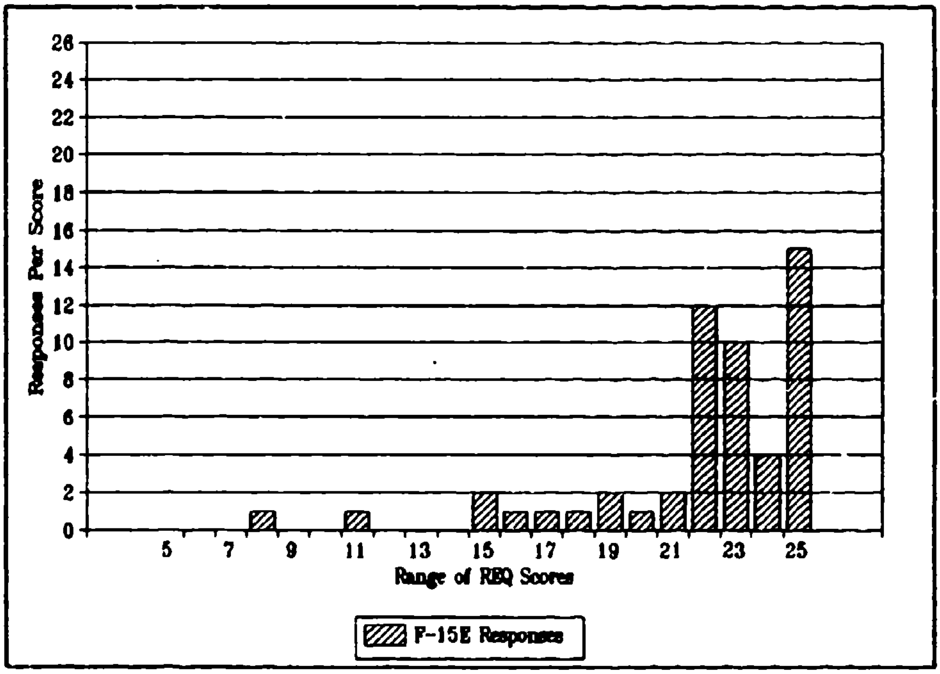

Figure 4-28. REQ Frequency Distribution, F-15E Pilots

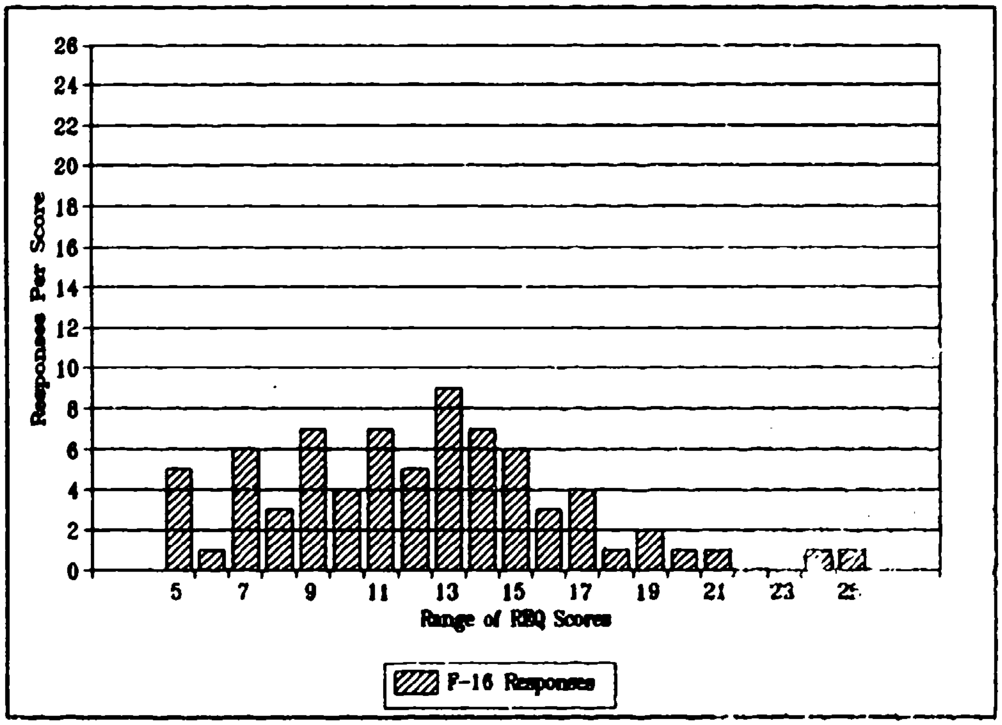

Figure 4-29. REQ Frequency Distribution, F-16 Pilots

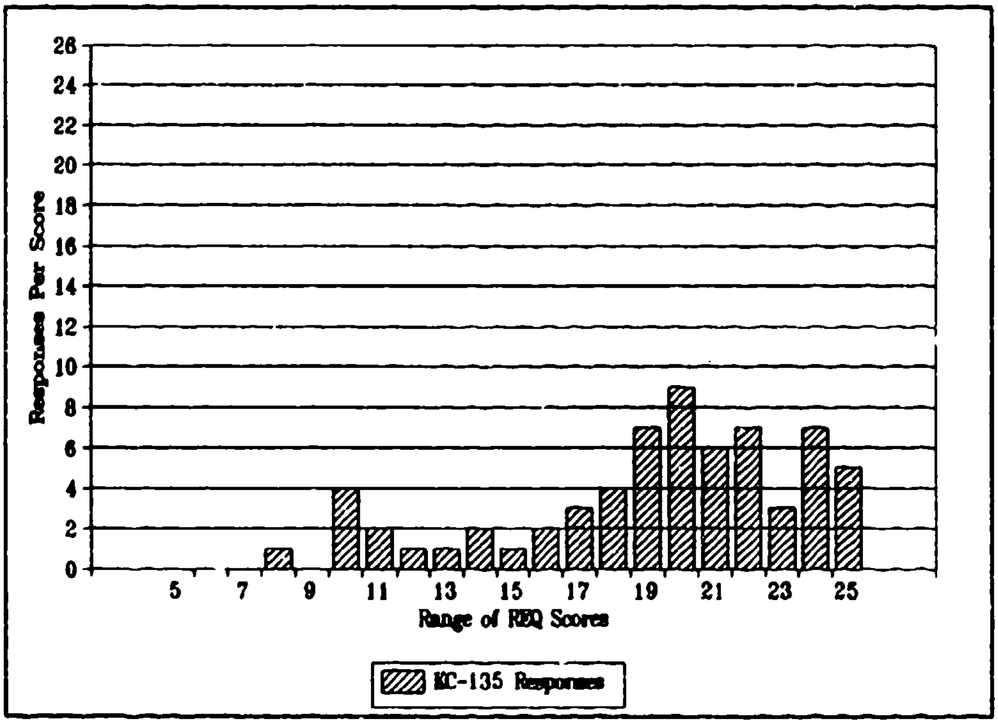

Figure 4-30. REQ Frequency Distribution, KC-135 Pilots

TABLE 4-19
RESULTS OF REQ STEPWISE REGRESSION USING SAMPLE DEMOGRAPHICS AS PREDICTORS

SURVEY DEMOGRAPHIC QUESTION	PARAMETER ESTIMATE	MODEL R^2	F	PROB > F
INTERCEPT	32.10549785		597.13	.0001
Q1 *	-0.51220772	.0335	16.11	.0001
Q6 **	-7.88443106	.4211	247.68	.0001

* Q1: What aircraft do you currently fly?
** Q6: Have you ever flown an airplane that included a Navigator/WSO/EWO as part of the crew?

The REQ model, like the NAVCRIT model should be used only to show the close relationship between the two demographic variables in the model. Like NAVCRIT, survey questions 1 and 6 appeared in the model. However, Question 4 was missing from the REQ model. Also like NAVCRIT, the REQ R^2 measure is too low to make this a credible model.

Stepwise regression was also attempted on individual aircraft types. Like NAVCRIT, the result was unusable.

The Bonferroni procedure for multiple comparisons was also applied to the REQ data. Table 4-20 summarizes the procedure's results:

TABLE 4-20
RESULTS OF MEANS COMPARISON BY AIRCRAFT OF REQ
(BONFERRONI T TESTS)

AIRCRAFT COMPARISON	DIFFERENCE BETWEEN MEANS	
B-52 - F-15E	0.2839	
B-52 - C-130	0.7829	
B-52 - KC-135	2.9213	***
B-52 - A-10	8.1079	***
B-52 - F-16	10.0488	***
F-15E - B-52	-0.2839	
F-15E - C-130	0.4990	
F-15E - KC-135	2.6369	***
F-15E - A-10	7.8240	***
F-15E - F-16	9.7949	***
C-130 - B-52	-0.7829	
C-130 - F-15E	-0.4990	
C-130 - KC-135	2.1384	***
C-130 - A-10	7.3250	***
C-130 - F-16	9.2659	***
KC-135 - B-52	-2.9213	***
KC-135 - F-15E	-2.6374	***
KC-135 - C-130	-2.1384	***
KC-135 - A-10	5.1866	***
KC-135 - F-16	7.1275	***
A-10 - B-52	-8.1079	***
A-10 - F-15E	-7.8240	***
A-10 - C-130	-7.3250	***
A-10 - KC-135	-5.1866	***
A-10 - F-16	1.9409	***
F-16 - B-52	-10.0488	***
F-16 - F-15E	-9.7649	***
F-16 - C-130	-9.2659	***
F-16 - KC-135	-7.1275	***
F-16 - A-10	-1.9409	***

*** Comparisons significant at the 0.95 confidence level
Alpha= .05, degrees of freedom= 391, MSE= 13.48693
Critical Value of T= 2.95335

Table 4-20 points out significant differences in the means of all six subject aircraft. These differences imply significant degrees of difference a navigator/WSO/EWO can make in the accomplishment of a mission. Table 4-21 summarizes the differences among the six aircraft:

TABLE 4-21
SUMMARY OF REQ MEANS BY AIRCRAFT OF THE PERCEIVED NEED FOR A NAVIGATOR/WSO/EWO FOR SUCCESSFUL MISSION ACCOMPLISHMENT

DEGREE OF NEED FOR A NAVIGATOR/WSO/EWO	AIRCRAFT
I (HIGHEST)	B-52/F-15E/C-130
II	KC-135
III	A-10
IV (LOWEST)	F-16

Tables 4-20 and 4-21 have two unexpected surprises in them. First, three very dissimilar aircraft display REQ means that are so close as to be insignificant. Pilots of B-52, F-15E, and C-130 aircraft have the highest perceived pilot need for a navigator/WSO/EWO in their respective aircraft. The second unexpected result is that there exists a significant difference in the means of the A-10 and F-16 samples. One must remember that the degrees shown in Table 4-19 possess no absolute low or high, but only shows differences among the six subject aircraft. Even with this limitation, the difference between the two single seat aircraft is surprising.

Chapter Summary

The demographics of the sample show a highly experienced group of respondents. Over half of the respondents have flown their current aircraft in combat. This group should provide excellent insight into the research conducted into this study and help add credibility to the study's findings.

The respondents provided new insight into mission effectiveness factors that are always critical and almost always critical to mission success. The respondents seem to share general agreement in the factors that are always critical to mission success. Differences began to appear in the next level factors--almost always critical to mission success.

The NAVCRIT and REQ measures uncovered varying degrees of importance of the navigator/WSO/EWO in accomplishing mission effectiveness factors and overall mission accomplishment. This analysis generally supported the findings of Chapter II.

The final step of this research effort will be to synthesize the data presented in this chapter with the previously published studies of Chapter II. Chapter V will perform this function and use this new knowledge to answer the questions raised in Chapter I.

V. CONCLUSIONS AND RECOMMENDATIONS

Chapter Overview and Introduction

This chapter's primary function is to integrate the established works explored in Chapter II and the knowledge learned from survey responses in Chapter IV. The result of these two pools of knowledge will be to answer the research question and its associated investigative questions and hypotheses of Chapter I.

This chapter is divided into six main parts. The first four parts will be devoted to answering each investigative question. The fifth section addresses the research question that has guided the research effort. The final section, section six, will recommend new avenues of research that could help Air Force decision-makers with the integration of advanced cockpit technologies into the next generation of Air Force aircraft.

Further clarification of the sections addressing the research investigative questions is required. Each section, or investigative question, will first be answered by individual aircraft surveyed. The second part of each investigative question will be a summation of trends from the entire survey sample. The answers to the investigative questions will be derived from the previous four chapters of this thesis and appendices related to the investigative question.

One appendix, Appendix B, Survey Comments ... ll be discussed because of its important qualitat... on the research and the timing of the research p... .n Appendix B, the users of today's combat aircraft voice their concerns and opinions on the next generation of weapon systems they may have to take to war. The comments in Appendix B were taken diroctly from Air Force pilots who took the time to write their feelings on the back of a long survey. Their comments are well thought out, articulate, and from their writings, represent deep convictions on this research question. The importance of the comments in the appendix cannot be over-emphasized.

The timing of the survey and survey comments is also important and unique. The surveys were mailed to prospective survey respondents just as many Air Force combat-tasked squadrons were re-deploying from combat operations in Southwest Asia. When the idea for this research project was in its infant stage in October, 1990, no one connected to the project anticipated that the United States would be at war in three months. As a result, this survey instrument gives Air Force leaders a "snapshot" in time that they may never again obtain in judging advanced cockpit technology incorporation in today's aircraft and its impact on combat operations. The good fortune of the survey timing gives this research effort credibility and authenticity that cannot be matched in computer simulations or theoretical studies. The term "snapshot" is especially applicable in this case. If this survey were to be administered in the summer of 1992, the researchers would not benefit from the experiences of the 1991 participants. With mandated force reductions and the lure of the commercial airlines, many pilots who responded to this survey might not be in the Air Force in 1992. It is doubtful that 1992 researchers would sample a population in which one out of every two pilots possesses combat experience. Therefore, the authors of this study feel that we owe the respondents to the survey who submitted written comments the chance to be heard.

Investigative Question 1: What do pilots of a particular aircraft type believe are the critical mission effectiveness factors for the mission they perform?

From a list of thirty-one potential critical mission effectiveness factors, pilots in six different aircraft types rated each factor on a scale from always critical to mission success to never critical to mission success. Most importantly, each pilot group, except pilots in the KC-135, selected factors they believed were always critical to mission success. This research effort was primarily interested in the always critical and almost always critical mission effectiveness factors.

A-10. A-10 pilots selected four factors as always critical. They were target acquisition, munitions employment, situational awareness, and threat avoidance

(Table 4-1). In addition, they selected 16 factors they believed were <u>almost</u> always critical to mission success (Table 4-2). Between the two categories of always and almost always critical mission effectiveness factors, the total number was 21 of a possible 31 that can be considered critical.

<u>B-52</u>. B-52 pilots also selected four factors as always critical. They were threat avoidance, situational awareness, threat detection, and crew coordination (Table 4-1). In addition, they selected 20 factors they believed to be <u>almost</u> always critical to mission success (Table 4-3). Between the two categories of always and almost always critical mission effectiveness factors, the total number was 24 out of a possible 31 that can be considered critical.

<u>C-130</u>. C-130 pilots also selected four factors as always critical to mission effectiveness. They were crew coordination, mission planning, situational awareness, and threat avoidance (Table 4-1). In addition, sampled C-130 pilots selected 21 factors they believed to be almost always critical to mission success (Table 4-4). In the two categories, the total number was 26 out of a possible 31 factors that can be considered critical.

<u>F-15E</u>. F-15E pilots selected seven factors as always critical to mission effectiveness. They were situational awareness, target acquisition, mission planning, munitions employment, threat avoidance, threat detection, and monitoring on-board avionics and weapons systems (Table 4-

1). In addition, these pilots selected 15 factors as almost always critical to mission success (Table 4-5). Combining responses in the two categories, the total number was 21 out of a possible 31 factors that can be considered critical.

F-16. F-16 pilots selected six factors they believed as always critical to mission effectiveness: mission planning, target acquisition, situational awareness, munitions employment, threat detection, and threat avoidance (Table 4-1). In addition, 17 factors were selected as almost always critical to mission success (Table 4-6). Between the two categoriss the total number of always and almost always critical mission effectiveness factors was 23 out of a possible 31 factors that can be considered critical.

KC-135. KC-135 pilots did not select any factors as always critical to mission effectiveness (Table 4-1). They did select 12 factors as almost always critical to mission effectiveness (Table 4-7).

From this data it is possible to conclude that pilots of each of these aircraft types believe there are critical mission effectiveness factors for the missions they perform. Five of the pilot groups selected a small number of factors as always critical to mission success.

To further probe the investigative question stated above, the researchers formed the hypothesis: "Each aircraft type will possess different critical mission effectiveness factors for the combat missions they perform."

The results of the research proved this hypothesis to be false. Instead of finding different critical mission effectiveness factors, the data showed a high degree of commonality among the factors selected as always critical to mission success. For example, situational awareness and threat avoidance appeared in all of the aircraft except the KC-135. In addition, target acquisition, munitions employment, threat detection, and mission planning all appeared in at least three of the aircraft. Only one factor, monitoring on-board avionics and weapons systems, appeared once in the always critical list.

Examining the six tables of almost always critical mission effectiveness factors, threads of commonality also existed. Flight safety appears in the top five factors for five of the aircraft. Aircraft maneuvering also appears at the top of these lists. Several factors such as mission planning, threat detection, and crew coordination, which were in the always critical list for some aircraft, are at the very tops of the almost always critical factor list in others. It is interesting to note that KC-135 pilots did not select any factors as always critical to mission effectiveness.

Conventional wisdom would lead one to believe that aircraft performing different types of missions would have different critical mission effectiveness factors affecting their success. However, this research shows that aircraft performing different missions actually have a high degree of commonality for the critical effectiveness factors required for mission success.

A natural conclusion is that aircraft operating under combat conditions, close to enemy resistance, require the same factors for mission success, regardless of their missions, whether they are attempting to destroy a target or deliver cargo. This conclusion may very well explain why pilots on the KC-135, an air-refueler, essentially flying a support mission many miles away from hostile activity, did not perceive any mission effectiveness factors as always critical to mission success. It may be that since the KC-135 does not encounter high threat combat conditions, its mission is not perceived as being as complex as those of aircraft that do encounter combat conditions. However, one would think KC-135 pilots would have judged such factors as flight safety, crew coordination, and mission planning as always critical to mission success, much like pilots in the other aircraft. These factors apply through all phases of the mission.

As stated in Chapter I, USAF aircraft are required to have the capability to perform effectively in a variety of unusual circumstances and various combat conditions. One respondent to the survey related a Desert Storm combat experience of flying his KC-135 into an area protected by Iraqi anti-aircraft artillery (AAA) and surface-to-air missiles (SAM) to refuel a flight of fighter aircraft. This comment demonstrates it is possible that even the KC-135 will face hostile fire due to extraordinary mission requirements. His full comments are in the KC-135 section in Appendix B. Although a majority of the KC-135 pilots surveyed did not perceive any factors as always critical to mission success, their perception might change if they encountered a scenario similar to the pilot who wrote about his experience in Desert Storm.

Investigative Question 2: Do the pilots of a particular aircraft type believe a Nav/WSO/EWO would enhance the performance of their aircraft concerning critical mission effectiveness factors for the mission it performs?

To answer this question, the researchers formed the hypothesis: A Nav/WSO/EWO is necessary to enhance critical mission effectiveness factors on combat missions.

NAVCRIT was the variable created by the researchers to draw conclusions about investigative question two. NAVCRIT was a measure of a pilot's perception of the necessity of a Nav/WSO/EWO to effectively perform selected critical mission effectiveness factors.

A-10. Figure 4-18 shows that the NAVCRIT scores for A-10 pilots ranged from 8 to 32. Visually the figure is skewed in favor of the low side. Over 60 percent of the A-10 pilots surveyed scored 19 or lower on the NAVCRIT scale. Two pilots scored the lowest possible score. In addition, Table 4-17 indicates that only the F-16 pilots had a lower mean NAVCRIT score. Table 4-17 also shows there is no statistical difference between the mean NAVCRIT scores of A-10 and F-16 pilots. Both possess low NAVCRIT scores. Table 4-18 indicates that the A-10 is in the lowest category of the perceived need for a Nav/WSO/EWO to enhance critical mission effectiveness factors. From the data it is possible to conclude A-10 pilots do not believe the presence of a Nav/WSO/EWO in the A-10 would much enhance the accomplishment of critical mission effectiveness factors.

There are two possible reasons for the low score. In Chapter IV a regression model was developed using experience and demographic factors as predictors of NAVCRIT scores. The results of the regression analysis were inconclusive; however, the question in which the pilots were asked if they had ever flown with a Nav/WSO/EWO was found to have a significant correlation of .4704. This correlation may indicate that a pilot's perception of the ability of a Nav/WSO/EWO to enhance the accomplishment of critical mission effectiveness depends on if the pilots have ever flown with Nav/WSO/EWOs and know their capabilities. The survey data reveals that only 12 out of 71 A-10 pilots have ever flown with a Nav/WSO/EWO; therefore, a large majority of A-10 pilots are unaware of the contributions the Nav/WSO/EWO might make to mission combat effectiveness.

The second reason the A-10 pilots received low NAVCRIT scores may be due to the attitudes of the pilots towards the mission they perform. In general, survey comments (Appendix B) indicate A-10 pilots do not believe their mission is complex enough to need a second crew member. One of the respondents specifically stated that a second crew member was not needed in close air support roles. This pilot's statement agrees with several studies cited in Chapter II. Furthermore, several respondents stated that they could see the need for a second person in a multi-role aircraft, but not in the A-10 (Appendix B).

F-16. Figure 4-22 shows that the NAVCRIT scores for F-16 pilots range from 8 to 37. Visually the figure is skewed in favor of the low side of the scale, much like that of the A-10. Over 67 percent of the F-16 pilots had NAVCRIT scores of 19 or lower. Two pilots had the lowest score of eight and two had a score of nine. In addition, Table 4-17 indicates that F-16 pilots had the lowest mean NAVCRIT score of all six aircraft Table 4-17 shows there is no statistical difference between the mean NAVCRIT scores of A-10 and F-16 pilots. In Table 4-18, the F-16 along with the A-10 is in the lowest category of the perceived need for a Nav/WSO/EWO to enhance critical mission effectiveness factors. The lowest category was established based on the closeness of the mean NAVCRIT scores. From the data presented, it is possible to conclude F-16 pilots do not believe the presence of a Nav/WSO/EWO in the F-16 would much enhance the accomplishment of critical mission effectiveness factors.

The low NAVCRIT scores for the F-16 are perhaps the hardest to explain. Introduction of the LANTIRN system to the F-16 enables it to perform night, low-level missions. F-16 pilot survey comments in Appendix B indicate the F-16 LANTIRN mission is extremely demanding and complex; one that may be better performed by a two-seat aircraft such as the F-15E or F-111. One respondent stated that "In my opinion, the tough missions against the tough threats will always require a two-man crew for maximum result." Another stated, "With the F-16's night mission Spatial Disorientation becomes a prominent factor, especially in a jet known for Spatial Disorientation - a WSO could only be an asset in this demanding mission as I could concentrate on flying and he could concentrate on targeting LANTIRN - two-seat only!" It seems F-16 pilots recognize the ability of a Nav/WSO/EWO to enhance the performance of critical combat effectiveness factors on sufficiently complex specialized missions, like the LANTIRN mission, but seem reluctant to admit the Nav/WSO/EWO would contribute to the basic mission of the F-16.

It is possible that a majority of the F-16 pilots share the attitude of the following respondent: "F-16's should have targeting pods and laser capability but should basically be DAY/VFR fighters that drop iron then go shoot people down. And it should remain single seat, single engine."

There are several possible reasons for the low scores of F-16 pilots. The first is identical to one suggested for the A-10. Only 25 of the 74 total respondents to the survey had ever flown with a Nav/WSO/EWO and, therefore, a majority simply do not know the capabilities of the Nav/WSO/EWO. A potential difficulty with this explanation is that compared to the A-10, twice as many F-16 pilots have flown with a Nav/WSO/EWO than A-10 pilots with approximately an equal number of respondents. One would expect that the F-16 NAVCRIT scores would be higher since more have flown with Nav/WSO/EWO's. In addition, survey comments indicate they do realize the value of a Nav/WSO/EWO for complex, demanding mission.

Another possible explanation is that F-16 pilots feel that technology enables them to perform effectively without a second crew member, even though LANTIRN systems increase the complexity of their mission. This belief is reflected in the comments of one respondent: "I do feel, having flown a lot at night in the F-117 and F-16 LANTIRN, that technology has brought us to the point where one man can do the job - low levels, attacks, survival, etc. at night."

The final explanation of the low F-16 NAVCRIT scores could be that F-16 pilots have a high confidence in their individual ability to perform their mission. To admit that the Nav/WSO/EWO could potentially enhance the accomplishment of critical factors of mission success could convey the perception that one cannot perform the mission, even though the mission has increased in complexity.

KC-135. Figure 4-23 shows that the scores for NAVCRIT among KC-135 respondents range from a low of 8 to a high of

39. Visually the figure is skewed in favor of the high side. Twenty percent of KC-135 pilots surveyed had NAVCRIT scores of 36 or higher. One pilot scored the lowest possible score. Table 4-17 indicates the KC-135 NAVCRIT score is higher than the A-10, but lower than the C-130. In addition, Table 4-17 shows that the mean NAVCRIT score is significantly different from the mean scores of the other aircraft, placing the KC-135 in a category by itself. Table 4-18 shows the mean KC-135 NAVCRIT score in the third lowest category. From the data it is possible to conclude KC-135 pilots place some value on the ability of the Nav/WSO/EWO to enhance the accomplishment of critical mission effectiveness factors. The value is greater than those of the A-10 and F-16, but less than those of the B-52, F-15E, and C-130.

The reason for the fairly low scores for KC-135 pilots may be that even though the Nav/WSO/EWO has flown on the KC-135 since its inception, the mission for the most part is not normally complex or especially hazardous. Furthermore, it may be that KC-135 pilots believe technology has advanced to a degree where it is possible to replace the Nav/WSO/EWO in the KC-135 cockpit. Here again it should be pointed out that due to mission requirements, USAF aircraft are tasked to perform in a variety of unusual circumstances and various combat conditions that the staff did not plan for and the aircrew may not have been trained to do. The KC-135 pilot's comments in Appendix B about avoiding AAA and SAM threats is a good example.

C-130. Figure 4-20 shows that the NAVCRIT scores for C-130 pilots ranged from 8 to 40. Visually the figure is skewed in favor of the high side of the scale. Forty-six percent of all C-130 pilots had NAVCRIT scores of 36 or higher. One pilot scored the lowest score. Table 4-17 indicates the C-130 mean NAVCRIT score is between the KC-135 and F-15E mean NAVCRIT scores. Table 4-17 also shows that the mean NAVCRIT scores between the C-130 and F-15E are not statistically significant. The test of significance between the C-130 and F-15E scores places the C-130 in the second highest category of the perceived need for a Nav/WSO/EWO for successful accomplishment of critical mission effectiveness factors(Table 4-18). From the data it is possible to conclude C-130 pilots believe the presence of a Nav/WSO/EWO in the C-130 enhances the accomplishment of critical mission effectiveness factors.

The relatively high mean C-130 NAVCRIT score in relation to the scores of the other aircraft seems to be explainable for two reasons. The correlation between high NAVCRIT scores and the variable of ever having flown with a Nav/WSO/EWO before offers a potential explanation. C-130 pilots have always flown with Nav/WSO/EWOs and, therefore, know their capability to enhance critical mission effectiveness factors.

Secondly, the score can be explained by comparing the complexity of the C-130 mission to the KC-135 and F-15E, the two aircraft scores it falls between. The complexity of the

C-130 mission is higher than that of the KC-135 because it is tasked with performing low level missions in potentially high threat environments. Therefore, one would expect the Nav/WSO/EWO to play a greater role in enhancing critical mission effectiveness factors. The obvious result would be a higher NAVCRIT score. In addition, if one assumes the most complex missions are those that not only involve night low-level phases but also the destruction of highly defended targets, then the C-130 mean NAVCRIT score naturally would fail below the F-15E NAVCRIT score. Even though the C-130 score does fall below the F-15E score, this research indicates statistically there is no difference.

Survey comments from C-130 pilots listed in Appendix B, in general, support the high mean C-130 NAVCRIT score. Comments indicate that the Nav/WSO/EWO duties could probably be replaced by advanced cockpit technologies; however, mission flexibility and effectiveness would be sacrificed.

F-15E. Figure 4-21 shows that the NAVCRIT scores for F-15E pilots ranged from 15 to 40. Visually the figure is heavily skewed in favor of the upper end of the NAVCRIT scale. One individual scored a 15 and one scored a 16. Fifty two percent of the responses possessed a score of 37 or higher. Table 4-17 indicates F-15E pilots had the second highest mean NAVCRIT score. Table 4-17 also shows that the mean NAVCRIT score of the F-15E is statistically close to both the B-52 and C-130 scores. This fact places the F-15E in the two top categories of degree of need for a

Nav/WSO/EWO (Table 4-18). From the data it is possible to conclude F-15E pilots have a strong belief that the Nav/WSO/EWO enhances the accomplishment of critical mission effectiveness factors.

There are three possible reasons why F-15E pilots obtained high NAVCRIT scores. The F-15E from the outset was designed as a two-person multi-role fighter. The ability to effectively perform the mission was designed around a team concept in which the Nav/WSO/EWO played an active role. The pilot from the very beginning of training learned how the Nav/WSO/EWO could enhance mission performance. Intentionally, the F-15E Replacement Training Unit (RTU) for Strike Eagle pilots from the beginning places a strong emphasizes on the role of the Nav/WSO/EWO and the "team concept".

A positive pilot attitude about the effectiveness of the Nav/WSO/EWO would lead to a high NAVCRIT score. This reason may also explain why the F-16 pilots had such low NAVCRIT scores, because a Nav/WSO/EWO position would be an add-on to the current F-16 cockpit configuration. The F-16 pilot might look at the Nav/WSO/EWO as an outsider who would force a change in their procedures and techniques to adapt to a two-person cockpit.

A second reason F-15E pilots achieved high NAVCRIT scores may be due to the complexity of the mission they perform. The night low level bombing mission in marginal weather against heavily defended targets can quickly lead to pilot task saturation. To efficiently perform the mission, a Nav/WSO/EWO is required.

Finally, having flown with a Nav/WSO/EWO, F-15E pilots are aware of the contribution they can make to effectively performing critical mission effectiveness factors. Readers are reminded that this fact alone resulted in the highest correlation with a high NAVCRIT score. The survey comments of F-15E pilots support the contention that the Nav/WSO/EWO enhances the performance of critical mission effectiveness factors. The following comment generally reflects the attitude of F-15 pilots: "Every combat aircraft in the Air Force should have two crew members. Anybody who says he can (by himself) fly in combat, while being shot at; possibly at night and at low level, while flying formation, avoiding threats and terrain, run the radar and targeting systems, and visually search for incoming threats either doesn't understand the workload or has an extremely inflated self-opinion."

B-52. Figure 4-19 shows that the NAVCRIT scores for B-52 pilots ranged from 25 to 40. Visually the figure is obviously skewed in favor of the high side of the scale. Fifty one percent of B-52 responses scored the maximum NAVCRIT score of twenty-five. Table 4-17 indicates that B-52 pilots had the highest mean NAVCRIT score. Table 4-17 also shows that there is no statistical difference between the B-52 and F-15E mean NAVCRIT scores. The high NAVCRIT score for the B-52 places it in the highest category of the degree of need for a Nav/WSO/EWO (Table 4-18). From the data, it is possible to conclude B-52 pilots have a strong belief that the Nav/WSO/EWO enhances the accomplishment of critical mission effectiveness factors.

Several conclusions are possible concerning the B-52 pilots' high NAVCRIT scores. B-52 pilots have always flown with a Nav/WSO/EWO and, therefore, realize the ability of the Nav/WSO/EWO to enhance the accomplishment of critical mission effectiveness factors. The regression routine showed there was a significant correlation between a high NAVCRIT score and a pilot's experience of having flown with a Nav/WSO/EWO (Table 4-16).

Another possible explanation for B-52 pilots achieving high NAVCRIT scores concerns technology. The B-52 uses older technology and requires a greater number of crew members to operate its systems. The B-52 pilot must rely heavily on additional crew members to effectively carry out the mission. The natural result is that the pilot perceives the Nav/WSO/EWO as essential to enhance the accomplishment of critical mission effectiveness factors. If the pilot were introduced to new cockpit automation technologies, the perception of the ability of the Nav/WSO/EWO to enhance critical mission effectiveness factors could be reduced. The B-2 bomber is an excellent example of how technology is seen as reducing the reliance on the need for air crew members.

A survey comment in Appendix B from a B-52 pilot supports this conclusion. he stated, "Your questions about technological advances replacing crew members are not valid when the survey participant is unaware of the advances you refer to. I'm sure some can replace a crew member, but in my aircraft I know that each person is very vital due to excessive workloads which can be created during attack or emergencies."

The number of missions the B-52 is called upon to perform is another explanation for the high NAVCRIT score of B-52 pilots. The B-52, like the F-15E, performs multiple complex missions. It performs conventional and nuclear missions, night or day, in all weather conditions, against high threat targets. B-52 pilots, due to the complexity of the mission they perform, involving numerous critical mission effectiveness factors, believe the Nav/WSO/EWO is essential to enhance the accomplishment of critical mission effectiveness factors.

An interesting point to note is the closeness of the mean NAVCRIT scores between B-52 and F-15 pilots (Table 4-17). The data supports the strong conclusion that the pilots of very different aircraft performing similar types of missions possess a strong belief in the ability of the Nav/WSO/EWO to enhance the accomplishment of critical mission effectiveness factors.

<u>NAVCRIT Summary</u>. One can conclude from the mean NAVCRIT scores that the pilot's belief in the ability of a

Nav/WSO/EWO to enhance critical mission effectiveness factors largely depends on 1) previous experience flying with a Nav/WSO/EWO; and 2) the various kinds and complexities of the missions performed.

The NAVCRIT scores increase as the complexity of the mission increases or the number of different types of missions an aircraft is tasked to perform increases. The F-16 was an exception to the general trend, because it had the second lowest NAVCRIT score and one of the more complex missions. The research data also showed that very different aircraft tasked to perform similar missions had comparable NAVCRIT scores, the most striking example being the B-52 and F-15E.

Results of the data did not support the hypothesis for the F-16, A-10, and KC-135 aircraft. The results of the research for the B-52, F-15E, and C-130 do support the hypothesis advanced at the beginning of this section.

Investigative Question 3: Does the perception of the need for a Nav/WSO/EWO depend on the type of mission flown?

To answer this question, the researchers formed the hypothesis: The perceived need for a Nav/WSO/EWO is based on the type of mission flown.

Investigative question two asked specifically about the Nav/WSO/EWO's impact on critical mission effectiveness factors that comprised a particular combat mission. Investigative question three is intended to be more global in nature than investigative question two. It does not focus on critical mission effectiveness factors that potentially comprise a mission, but focuses on an entire mission (e.g. close air support).

REQ was the variable created by the researchers to draw conclusions about investigative question three. REQ was a measure of a pilot's perception of the need for a Nav/WSO/EWO based on the type of mission flown. The same procedures used to analyze NAVCRIT were used to analyze REQ.

A-10. Figure 4-25 shows the distribution of REQ scores for A-10 pilots. They range from the lowest possible score of 5 to 24. Visually the distribution is skewed slightly left of center. Over 61 percent of the sampled A-10 pilots had scores less than 20. Table 4-20 indicates A-10 pilots received the second lowest score of the six aircraft. Table 4-20 also shows the mean A-10 REQ score was statistically different from the other aircraft mean REQ scores. This fact placed the A-10 by itself in the third lowest category for the degree of need for a Nav/WSO/EWO (Table 4-21). From the data it is possible to conclude that A-10 pilots do not strongly believe the need for a Nav/WSO/EWO depends on the mission.

The possible reasons for the low score are much the same as those for NAVCRIT. A regression model was developed for REQ using experience and demographic factors as predictors of REQ scores. The results of this regression analysis were also inconclusive; however, the question in which the pilots were asked if they had ever flown with a nav/WSO/EWO was found to have a significant, though low, correlation of .4211. This correlation may indicate that a pilot's perception of the requirement for a Nav/WSO/EWO depends on the pilots' ever having flown with Nav/WSO/EWOs and known their capabilities. Because a large majority of A-10 pilots have never flown with a Nav/WSO/EWO, they are possibly unaware of the Nav/WSO/EWOs contributions to combat mission effectiveness. The following comment from the survey illustrates the point, "I have always been a single seat aviator in A-10, F-117A, and the A-7E with the U.S. Navy. I'm sure I am not a reliable source for "crew member" questions. I can only give opinions."

Another reason the A-10 pilots do not believe the need for a Nav/WSO/EWO depends on the mission is that they may be answering the questions based on the mission they perform. In this case, their score would reflect their feelings about the Nav/WSO/EWO concerning their mission. As with NAVCRIT, A-10 pilots do not believe the mission is complex enough to need a second crew member.

Even though the A-10 mean REQ score was low compared to the responses of pilots of other aircraft, the survey comments indicate some of the respondents believe the requirement for a Nav/WSO/EWO does depend on the mission. One respondent commented, "Crew tactical fighters have a place in multi-role aircraft for workload reduction in high task situations. However, it's not needed in close air support roles." In general one can conclude that A-10 pilots believe the Nav/WSO/EWO is required for some types of missions. However, they also believe the Nav/WSO/EWO is not needed in their aircraft for the close air support mission.

F-16. Figure 4-29 shows the distribution of REQ scores for F-16 pilots. They range from the lowest possible score of 5 to 25. Visually, the distribution is skewed to the left of center. Over 64 percent of the sampled F-16 pilots had scores less than 20. Table 4-20 indicates F-16 pilots received the lowest score of the six aircraft. Table 4-20 also shows the mean F-16 REQ score was statistically different from the other aircraft mean REQ scores. Table 4-21 shows the F-16 in the lowest category for degree of need for a Nav/WSO/EWO. Like NAVCRIT, the F-16 is in the lowest possible category. From the data it is possible to conclude that F-16 pilots do not strongly believe the need for a Nav/WSO/EWO depends on the mission.

Here again it is possible to use the results of the regression models to explain the F-16 pilots' low REQ score. The significant correlation indicates that a pilot's perception of the requirement for a Nav/WSO/EWO depends on the pilots' ever having flown with a Nav/WSO/EWO. Because a majority of F-16 pilots have never flown with a Nav/WSO/EWO, they are possibly not aware of the capabilities of the Nav/WSO/EWO to contribute to combat mission success. The following survey comment by an F-16 pilot illustrated the point: "I'm probably a poor choice to answer this survey having never flown an aircraft with a Nav/WSO/EWO."

Another reason may be that F-16 pilots feel that technology enables them to perform effectively without a second crew member. Comments used earlier in NAVCRIT show this could be a possible explanation.

Even though the data indicates F-16 pilots received the lowest REQ score and, therefore, do not strongly believe the requirement for a Nav/WSO/EWO depends on the mission, their survey comments indicate otherwise. One survey respondent observed that "It pays to have an extra set of eyeballs and hands on-board these days. Depends on the mission and threat." Another respondent commented, "The complexity and task intensity of F-16 LANTIRN and F-15E missions could well demand a second crew member."

If F-16 pilots do believe the requirement for a Nav/WSO/EWO depends on the mission, then a possible explanation for the low REQ score could be that they answered the questions in light of admitting the need for a Nav/WSO/EWO in their airplane. The conclusion would then be that they do not want a Nav/WSO/EWO in their airplane. Comments from the survey seem to suggest this. One respondent commented, "F-16's don't need WSO's." Another said, "Most single seat pilots like being alone in their jet."

The contradiction here is while admitting the F-16 low-level nighttime combat mission may require an additional crew member to perform its mission and that the missions may be better performed by an F-15E, F-16 pilots simply do not want the additional crew member in their cockpit. It seems they would be satisfied using the F-16 to perform strictly daylight, clear weather missions and leave more demanding missions (like LANTIRN) to multiple crew airplanes. In general, one can conclude that even though the F-16 performs increasingly complex missions and F-16 pilots believe Nav/WSO/EWOs are required on some types of missions, they do not believe a Nav/WSO/EWO is required in their aircraft.

KC-135. Figure 4-30 shows the distribution of REQ scores for KC-135 pilots. They range from a low score of 8 to the highest possible score of 25. Visually the distribution is skewed slightly to the right of center. The KC-135 represented the middle ground in REQ scoring. Over 51 percent of the KC-135 sample scored between 18 and 22 inclusive. The KC-135 sample did not possess the high number of respondents in the over 21 range like the B-52/F-15E/C-130 scores. Table 4-20 indicates the KC-135 received a mean REQ score between the A-10 and C-130. Table 4-20 also shows the mean KC-135 REQ score was statistically different from the other aircraft mean REQ scores. Table 4-21 places the KC-135 in the second highest category for the degree of need for a Nav/WSO/EWO. From the data it is possible to conclude that KC-135 pilots moderately believe the need for a Nav/WSO/EWO depends on the mission.

A possible explanation for the moderate REQ score is that the KC-135 pilots (like the A-10 and F-16 pilots) answered the questions for REQ in regard to the need for a Nav/WSO/EWO on their aircraft. The REQ score is then an expression of the requirement for a Nav/WSO/EWO for missions they perform in their aircraft. The moderate score may be a result of the KC-135 pilots' perception that the mission they perform for the most part is not normally complex or especially hazardous. The following comment from a survey respondent illustrates the point: "As I flew only combat support sorties, it is very difficult to comment on combat oriented questions." In comparison to missions performed by other aircraft, the KC-135 mission would not be considered complex. In addition, the moderate score may reflect that KC-135 pilots believe technology has advanced to a degree where it is possible to replace the Nav/WSO/EWO with new cockpit automation technology. A comment from the same survey respondent above illustrates this point, "The Nav is essential with existing cockpit equipment. Place a color radar, double INS, and/or GPS in the cockpit, and we don't need a Nav."

In general, based on the REQ score and survey comments, it is possible to conclude that KC-135 pilots believe Nav/WSO/EWOs may be required on some missions they fly, but with the right technologically advanced avionics, they do not need a Nav/WSO/EWO.

C-130. Figure 4-27 shows the distribution of REQ scores for C-130. They range from the lowest possible score of 5 to the highest possible score of 25. Visually the distribution is skewed sharply to the right. Sixty-four percent of the sampled C-130 respondents have REQ scores greater than 21. Table 4-20 indicates the C-130 mean REQ score was the third highest among the six aircraft. Table 4-20 also shows there is no statistical difference between the C-130 mean REQ score and those of the F-15E and B-52. Table 4-21 shows the mean REQ score is in the highest category for the degree of need for a Nav/WSO/EWO. From the data it is possible to conclude that C-130 pilots strongly believe the need for a Nav/WSO/EWO depends on the mission. Possible reasons for the high REQ scores for C-130 pilots are the same as they were for NAVCRIT. The requirement for the C-130 to perform low level missions, possibly at night near hostile enemy actions, makes the C-130 mission one of the most complex and demanding. The high REQ scores support the conclusion that due to this complexity, C-130 pilots strongly believe the Nav/WSO/EWO is required in their aircraft. The following comment illustrates the point: "C-130's will no longer need nav's for airland missions but no electronics can replace a nav on low-level airdrop and austere airland missions, day or night."

Another possible reason for the high REQ scores is that C-130 pilots have always flown with Nav/WSO/EWOs and are familiar with their ability to enhance mission effectiveness.

Finally, another reason for the high REQ scores is that the degree of technology used on the C-130 makes the pilot dependent on the Nav/WSO/EWO to perform certain cockpit duties. With the current level of technology, the Nav/WSO/EWO is required to perform an effective mission. However, if cockpit automation technologies were introduced into the cockpit, the requirement for a Nav/WSO/EWO would be much less. One respondent addressed this argument by saying, "I feel it is important to retain navigators/EWOs even with the advent of advanced navigation technologies to avoid pilot task saturation, and to assure mission tasking flexibility."

F-15E. Figure 4-28 shows the distribution of REQ scores for F-15E pilots. They range from a low score of 8 to the highest possible score of 25. Visually the distribution is highly skewed to the high side of the scale. Over 77 percent of F-15E pilots surveyed have REQ scores greater than 21. Table 4-20 indicates the mean REQ score for F-15E pilots was the second highest. Table 4-20 also indicates there is no statistical difference between the F-15E mean REQ score and the B-52 and C-130. Table 4-21 shows the F-15E REQ score in the highest possible category of the degree of need for a Nav/WSO/EWO. From the data it is possible to conclude F-15E pilots strongly believe the requirement for a Nav/WSO/EWO is mission dependent.

The reasons for the high REQ scores are the same as they were for NAVCRIT. The complexity of the F-15E mission drives the requirement for a Nav/WSO/EWO. The requirement for the F-15E to perform numerous different missions under high threat conditions requires a Nav/WSO/EWO to prevent pilot task saturation. The requirement for the Nav/WSO/EWO is high even though the F-15E uses modern, up-to-date, cockpit technologies. The performance of the F-15E would lead one to conclude that even with the latest technology incorporated, a second crew member is necessary to effectively perform its mission. The following comment aptly demonstrates the point: "Technology is great, but cannot replace the backseater." Another respondent said, "Single seat (F-16's) in Desert Storm were far (by a factor of three times) more likely to miss their target and return to base with bombs unexpended, even with "new cockpit technologies". New cockpit technologies did not provide the same increase of combat effectiveness that a WSO/EWO would provide."

The results of the survey from the F-15E perspective strongly support the contention that the requirement for a Nav/WSO/EWO is mission dependent. It appears this need was demonstrated in Desert Storm.

B-52. Figure 4-26 shows the distribution of REQ scores for B-52 pilots. They range from a low of 15 to a high of 25. Visually, the distribution is heavily skewed to the high end of the REQ scale. Over 68 percent of surveyed B-52 pilots had REQ scores greater than 21. Table 4-20 indicates B-52 pilots had the highest mean REQ score of all six aircraft. Table 4-20 also indicates there was no statistical difference between the mean REQ score for the B-52 and those of the F-15E and C-130. Table 4-21 shows the B-52 in the highest category of degree of need for a Nav/WSO/EWO. From the data it is possible to conclude B-52 pilots strongly believe the requirement for the Nav/WSO/EWO depends on the mission.

The reasons for the high REQ score for the B-52 are the same as for the NAVCRIT scores. Like the F-15E, the B-52 is required to perform multiple complex missions under high threat conditions. The Nav/WSO/EWO is required to give the B-52 the flexibility it needs to be effectively employed under multiple mission scenarios. It is interesting to note the similarity between the B-52 and F-15E REQ scores. This was also the case with their NAVCRIT scores. The F-15E and the B-52 are two very different aircraft, which use different levels of technology to perform the most demanding and complex combat missions. Both are used to perform multiple combat roles. The similarity in their scores would lead one to develop a strong conclusion that the Nav/WSO/EWO requirement depends on the type of mission performed.

Another explanation for the high B-52 REQ scores may be that B-52 pilots have always flown with a Nav/WSO/EWO, know their capabilities, and depend on them to perform essential cockpit duties. It may be that current levels of cockpit technology incorporated on the B-52 may drive the requirement for a Nav/WSO/EWO. If new technology were introduced into the B-52 cockpit, it would make it possible to eliminate several crew members. The B-1 demonstrates that it can be done.

REQ Summary. The REQ scores follow the same pattern as the NAVCRIT scores. As with the NAVCRIT scores, one can conclude that the pilots' belief that the requirement for a Nav/WSO/EWO for a particular mission generally depends on 1) previous flying experience with a Nav/WSO/EWO; and 2) the complexity of the mission.

The REQ scores increased as the complexity of the mission increased. Here again the F-16 was the exception to the general trend, because its pilots had the lowest REQ score while increasingly being tasked to perform more complex missions. The research data for REQ also showed, like NAVCRIT, that different aircraft types using different levels of technology to perform similar types of missions have comparable REQ scores.

The hypothesis advanced at the beginning of this section was not supported by the research data for the F-16, A-10, and KC-135. The results of the data for the B-52, F-15E, and C-130 did support the hypothesis that the requirement for a Nav/WSO/EWO depends on the type of mission flown.

Investigative Question 4: Does the perception of the need for a Nav/WSO/EWO depend on the experience level of the pilot?

To answer the question the researchers formulated the following hypothesis: More experienced pilots will recognize the benefits of a Nav/WSO/EWO in helping to effectively perform the mission they fly.

Stepwise regression was performed on both the mean NAVCRIT scores and the mean REQ scores to determine which experience factors could be used to predict a pilot's particular viewpoint. The results were somewhat disappointing. The researchers expected that the number of flying hours or the number of combat flying hours would determine a pilot's belief in the ability of the Nav/WSO/EWO to enhance combat effectiveness. This was not the case.

Initially, stepwise regression was performed on each separate aircraft's NAVCRIT and REQ scores using the demographic factors of the pilot for each aircraft type. No demographic factors were found to significantly correlate with NAVCRIT and REQ scores for the individual aircraft types. However, when all six aircraft were taken together, significant factors did appear. The results of the NAVCRIT stepwise routine are listed in Table 4-16, and the results of the REQ stepwise routine are listed in Table 4-19.

The most significant predictor of NAVCRIT was whether a pilot had ever flown in an airplane that included a Nav/WSO/EWO. This was also the case with REQ. Even though this variable was significant, the model significance was low. The result of the analysis would lead to the conclusion that the pilots' perceptions of the ability of the Nav/WSO/EWO to enhance combat effectiveness is simply dependent upon their knowledge of the capabilities of the Nav/WSO/EWO.

Two other predictors were identified for NAVCRIT and one for REQ. Even though the variables were determined to be significant, the model significance remained low. The question, "What aircraft do you currently fly?" was significant for both NAVCRIT and REQ. The question, "Were you qualified to fly in any other operational aircraft prior to the one you currently fly?" was the third significant variable for NAVCRIT.

Even though the significance of the demographic characteristics to explain pilot response about the impact of the Nav/WSO/EWO on combat effectiveness was low, it should not be ignored. The relationships do help to explain the low scores achieved by F-16 and A-10 pilots for NAVCRIT and REQ.

The inability of this research effort to identify significant predictors of pilot response suggests other factors may more adequately explain pilot attitudes concerning the impact the Nav/WSO/EWO has on combat effectiveness.

The explanation may depend on common attitudes and perspectives that are developed in different aircraft squadrons. The pilots' belief in the ability of Nav/WSO/EWOs to enhance their performance may actually depend on the confidence level of the pilots to perform the mission themselves, without assistance. This conclusion is somewhat supported by the responses given by F-16 pilots. Their responses indicate a Nav/WSO/EWO may be helpful on some missions, but not theirs. A common explanation may not exist at all.

The research data in general does not support the hypothesis that more experienced pilots will recognize the benefits of a Nav/WSO/EWO in helping to effectively perform the missions they fly.

Research Question

The overall goal of this research effort was to answer the research question: Do pilots believe the Nav/WSO/EWO can effectively be replaced by new cockpit automation technologies on aircraft performing missions in high threat combat environments?

The data collected for this research supports the findings of studies discussed in the literature review. In addition, the identical results of two different measures (NAVCRIT and REQ) of pilot attitudes concerning the impact of the Nav/WSO/EWO on combat mission effectiveness lend validity to the conclusions of this research effort. The overall conclusion from the data gathered from this study is that pilots of USAF aircraft do not believe it is possible to effectively replace the Nav/WSO/EWO with technology for aircraft performing high threat combat missions.

The results generally indicate that for aircraft performing missions that are perceived not to be extremely complex or demanding, it is possible to replace the Nav/WSO/EWO with advanced technology and not sacrifice mission effectiveness. This point was illustrated by the responses of A-10 and KC-135 pilots. Both of these groups in general viewed their missions not to be complex. The caveat made by the KC-135 pilots was that it is possible to replace the Nav/WSO/EWO with technology as long as the equipment works as it should. If equipment does not operate properly, the pilot is in danger of task saturation and the effectiveness of the mission will be reduced.

As the missions discussed in this research become more complex and demanding, the responses of pilots who have to fly them generally indicated it is not possible to replace the Nav/WSO/EWO with technology without a high probability of sacrificing mission effectiveness. The more complex missions were those that included night low-level taskings in areas of high enemy threats. B-52 pilots and especially F-15E pilots felt very strongly that technology should not be used to eliminate the Nav/WSO/EWO positions; rather, it should be used to enhance the performance of the Nav/WSO/EWO to improve overall mission effectiveness. The scores of B-52 and F-15E pilots for NAVCRIT and REQ were statistically close at the 95 percent confidence level. Examining the missions they are tasked to perform, one finds that both are tasked to fly multiple types of missions under various combat conditions. It is interesting to note that the scores are comparable even though the aircraft are dissimilar and reflect different levels of cockpit technology. One is led to conclude that the level of technology does not drive the requirement for a Nav/WSO/EWO; rather, it is the complexity of the mission that determines the requirement for a Nav/WSO/EWO.

The one exception to the trend is the response given by F-16 pilots. The F-16 incorporates the latest cockpit automation technology and has increasingly been tasked to fly a greater number of more complex missions. One would expect positive attitudes about the need for a second crew member to help perform the mission and prevent pilot task saturation. However, the attitudes reflected in their NAVCRIT and REQ scores, and in their survey comments, indicated they did not believe a Nav/WSO/EWO would enhance their combat effectiveness even though they felt they were flying more complex missions due to technology enhancements like LANTIRN. From survey comments, it appears that F-16 pilots believe the more complex missions that utilize the LANTIRN system should be left to two seat aircraft that can more effectively perform the mission.

Based on the results of this research, it seems Air Force decision-makers would want to reconsider the current trends in the USAF to acquire new aircraft that incorporate new cockpit technology at the expense of eliminating the Nav/WSO/EWO. The results of this research reflect the attitudes and perceptions of many pilots who fought in Desert Storm. They possess relevant information about the performance of USAF aircraft under actual combat conditions. A significant finding of this research is that many pilots believe replacing the Nav/WSO/EWO on aircraft performing operations in high threat combat areas will make the aircraft less effective in performing its mission. It is evident from this research that many pilots performing important missions in current aircraft believe the role of technology should be to enhance the performance of Nav/WSO/EWOs rather than replace them for certain types of missions. Those missions that are candidates for the use of a multi-place crew are low-level attack missions, flown at night in possible adverse weather, against heavily defended enemy targets.

The acquisition of any new aircraft should include an evaluation of the complexities of the mission the aircraft will be tasked to perform. Specifically, the study should include a cost/benefit analysis comparing potential cost savings that accrue from reductions in personnel compared to likely trade-offs in aircraft performance with resulting impacts on combat effectiveness. Furthermore, one would want to compare the differences in aircraft performance due to the weight of a person in a cockpit compared to the weight of the equipment that replaces the individual. A study investigating the issues surrounding crew complement for new aircraft would appropriately take place in the concept/exploration phase of the acquistion process where alternative concepts to meet the threat are explored.

In today's high performance aircraft, the addition of an extra person to a single seat cockpit will have minimal impact on the ability of an aircraft to pull nine G's. The point is aptly illustrated by the following comment from an F-16 pilot: "The F-16 would only be hampered by the 1300 pounds of fuel we lose. With the F110 engine-the BLK 40 F-16-nothing can be too much drag to be ineffective. We've basically taken a 200 pound man and replaced him with 1500 pounds of Nav and targeting pods accounting for 53 units of drag. He would only add another 10-15 drag units. With the F-16's night mission--Spatial Disorientation becomes a prominent factor, especially in a jet known for Spatial D [isorientation]--a WSO could only be an asset in this demanding mission as I could concentrate on flying and he could concentrate on targeting. LANTIRN-two seat only!" The comment above indicates that the only significant impact on aircraft performance is the impact on 1300 pounds of fuel. If this is so, then it seems appropriate to suggest any analysis should focus on the mission impact of the availability of fuel compared to potential increases in combat mission effectiveness of placing a Nav/WSO/EWO in the cockpit. This research shows that the resulting increases in combat effectiveness may outweigh any personnel cost savings and reductions in aircraft performance due to the addition of a Nav/WSO/EWO to a cockpit. Because personnel cost savings seem to be the major reason for replacing the Nav/WSO/EWO, then the question Air Force leaders and decision-makers will have to address is how much combat effectiveness they are willing to give up in order to realize potential savings.

It is unlikely that the crew complement of already developed aircraft, such as the F-22 and C-17, could be changed. A cockpit design change at this point would only delay the programs and result in increased costs. However, the development of the next generation of aircraft still on the drawing boards, such as the dual role fighter to replace the F-15E and F-16, should strongly consider the impact on combat mission effectiveness of replacing the Nav/WSO/EWO with advanced technology. Perhaps the best solution for the next dual-role fighter (DRF) would be to purchase a mix of single seat and two seat aircraft. This mix would provide commanders with the increased flexibility they need to counter various enemy threats.

As the world witnesses the collapse of communism, Congress and the Executive branch will face increased pressures to reduce defense spending. Air Force leaders and decision-makers facing shrinking budgets will be forced to select only those weapon systems that offer the greatest flexibility in combat performance at an affordable price. The weapon systems providing commanders with the greatest flexibility will be those able to perform multiple missions. Shrinking defense budgets will not allow the purchase of many different specialized weapons to perform specialized missions as they have historically. Air Force aircraft of the future, as they were in Desert Storm, will be called upon to fight under various combat conditions dictated by unplanned mission requirements. Multi-place aircraft are a means to ensure the Air Force will be able to concentrate the firepower of its weapon systems effectively against the enemy regardless of the mission scenario.

Further Research

This research effort suggests future research in several areas.

1. A follow-up of this study could be conducted. The same survey instrument with minor corrections could be used to sample USAF pilots of several other aircraft types. It could be sent to pilots in the F-117, F-111, and the B-1 as a minimum. The results could be used to further explore the impact of increased technology and reduced manning of the Nav/WSO/EWO position on combat effectiveness. The results could increase the validity of the survey instrument and the validity of this research effort.

2. A follow-up study that sampled pilots flying aircraft in other service would also be useful in further exploring the impact technology and the Nav/WSO/EWO have on the combat effectiveness of aircraft of other services.

3. A computer simulation that simulates aircraft of different crew complements attacking identical targets would

provide useful insights into the impact of the Nav/WSO/EWO. One would be able to accurately compare the effectiveness of a single seat aircraft compared to a two seat aircraft for different mission such as day strike, night strike, close air support, and air interdiction. In addition, one could gather and compare data concerning target destruction, threat avoidance, threat detection and loss rates for various mission. Finally, one could calculate the costs of operating aircraft squadrons with and without Nav/WSO/EWOs and compare to the costs to the different mission effectiveness rates for each squadron.

Summary

The overall goal of this chapter was to answer the research question proposed in Chapter I. The question was: Do pilots believe the Nav/WSO/EWO can effectively be replaced by new cockpit automation technologies on aircraft performing missions in high threat combat environments? Four investigative questions were formulated to guide the research effort and aid the researchers in answering the research question. Each question was discussed by aircraft type using the data presented in Chapter IV. Focusing on the research question, the researchers concluded that a large majority of pilots believe the Nav/WSO/EWO can not effectively be replaced by advanced cockpit technology on aircraft performing missions in high threat combat environments. For complex combat missions, the role of advanced cockpit technology should be to enhance the performance of the Nav\WSO\EWO rather than replace them. The chapter concluded with suggestions for further research.

Appendix A: Cover Letter and Survey

INSTRUCTIONS

This survey is designed for U.S. Air Force officers who have attained the aeronautical rating of **PILOT, SENIOR PILOT, OR COMMAND PILOT**. These individuals are the only personnel that should fill out the questionnaire.

This questionnaire contains 80 items (individual "questions"). All but two of the items are to be answered on the accompanying answer sheet, AFIT Form 11C. The remaining two questions are to be answered in the questionnaire booklet. The questionnaire and the computer answer sheet should be returned via U.S. Mail in the pre-addressed envelope provided.

Please use a "soft-lead" (No. 2) pencil, and observe the following:

1. Make heavy black marks.
2. Erase cleanly.
3. Make no stray markings.
4. Do not staple, fold, or tear the response sheet.

Do **NOT** fill in your name on this answer sheet or the questionnaire so that your response will be anonymous.

Some questions give you the option of selecting "other (specify)" as an answer. If you select the "other" option as an answer, specify your answer **AND** mark the associated block on the computer answer sheet.

USAF Survey Control Number (SCN): 91-34
Expiration Date: 30 September 1991

Survey Questionnaire

USAF PILOT SURVEY OF COMBAT EFFECTIVENESS FACTORS AND THE NEED FOR AN ADDITIONAL CREW MEMBER

BIOGRAPHICAL DATA

1. What aircraft do you currently fly?

1. A-10	4. F-15E
2. B-52	5. F-16
3. C-130	6. KC-135

For questions 2 and 3, use the following responses to answer the questions.

1. Under 250	6. 1,001 - 1,500
2. 251 - 500	7. 1,501 - 2,000
3. 501 - 750	8. 2,001 - 2,500
4. 751 - 1,000	9. 2,501 - 3,000
5. 1,001 - 1,500	10. Over 3,000

2. How many flying hours have you accumulated in the aircraft you are currently flying?

3. How many total flying hours have you accumulated?

4. Prior to being qualified in the aircraft you selected in question 1, were you qualified to fly any other operational, **NOT** trainer, aircraft?

   1. Yes (Please Specify Aircraft: ______________________)

   2. No

5. **ANSWER THIS QUESTION ONLY IF YOU HAVE EVER HELD THE AERONAUTICAL RATING OF NAVIGATOR.** Which type of navigation duty did you perform while rated as a navigator?

1. Navigator (Bomber, Tanker, or Transport Aircraft)

2. Electronic Warfare Officer (EWO) (Bomber, Strategic Reconnaissance, or other Non-Fighter Type Aircraft)

3. Electronic Warfare Officer (EWO) (Fighter Aircraft)

4. Weapon System Officer (WSO) (Fighter Aircraft)

6. Have you ever flown an airplane that included a Navigator/WSO/EWO as part of the crew?

1. Yes

2. No

For questions 7, 8, and 9, please use the scale shown below to answer the questions.

1. None	5. 301 - 400
2. Less than 100	6. 401 - 500
3. 101 - 200	7. 501 - 1,000
4. 201 - 300	8. Over 1,000

7. How much <u>combat</u> time have you accumulated in the aircraft you are currently qualified to fly?

8. How much <u>total combat</u> time have you accumulated as a military pilot? (Please Specify Conflicts You Fought In--
____)

9. **ANSWER THIS QUESTION ONLY IF YOU HAVE EVER HELD THE AERONAUTICAL RATING OF NAVIGATOR.** How much <u>combat</u> time did you accumulate as a Navigator/EWO/WSO?

10. Have you ever been qualified as an Instructor Pilot in an operational, **NOT** trainer, aircraft?

1. Yes

2. No

11. Have you ever been qualified as a Flight Evaluator in an operational, **NOT** trainer, aircraft?

1. Yes
2. No

12. Have you ever been qualified as a Wing Weapons & Tactics Officer in an operational, **NOT** trainer, aircraft?

1. Yes
2. No

13. Have you flown in any exercises (FLAG exercises), unit competitions (WILLIAM TELL, SAC Bombing Competitions, or Reconnaissance Air Meet), or any joint exercises as a participant?

1. Yes
2. No

14. What is your current rank?

1. 2Lt	3. Capt	5. Lt Col	7. General
2. 1Lt	4. Major	6. Col	

15. What is the primary mission of your unit during wartime?

1. Strategic Deterrence
2. Conventional Heavy Bombing Operations
3. Theater Airlift
4. Tactical Airlift
5. Air-to-Air Refueling
6. Air Superiority
7. Close Air Support
8. Air Interdiction
9. Other (specify) ______________________________

MISSION EFFECTIVENESS FACTORS

Items 16 - 46 represent factors that may be critical to the combat effectiveness of a combat mission you may fly. Use the following scale to rate the degree of criticality of each factor:

CRITICAL FACTOR RATING SCALE

1	2	3	4	5
Always Critical To Mission Success	**Almost Always Critical To Mission Success**	**Can be Critical**	**Almost Never Critical**	**Never Critical**

16. Ability to Fly in Adverse Weather/ Low Inflight Visibility

17. Mission Planning

18. Monitoring On-Board Avionics & Weapon Systems

19. Flight Safety

20. Equipment Degradation During Mission

21. Low Level Navigation

22. Night Low Level Navigation

23. Threat Avoidance

24. Formation Management

25. Management of Time Over Target (TOT)

26. Inflight, No-Notice Mission Changes

27. Targets of Opportunity

28. Munitions Employment

29. Threat Detection

30. Level of Aircrew Taskings

31. Ability to Handle Crew Member Incapacitation

32. Ability to Handle Inflight Emergencies

33. Visual Lookout

CRITICAL FACTOR RATING SCALE

1	2	3	4	5
Always Critical To Mission Success	Almost Always Critical To Mission Success	Can be Critical	Almost Never Critical	Never Critical

34. Command & Control (Includes copying and decoding EAMS)

35. Crew Fatigue

36. Crew Coordination

37. Aircraft Maneuvering (To avoid air and ground threats and no fly areas)

38. Situational Awareness

39. Target Acquisition

40. Visual Drop Capability

41. Night Operations

42. High Speed Air Drop

43. Station Keeping

44. Aircrew Workload

45. Short-Unimproved Airfield Operations

46. Terrain Avoidance/Following

A. If this survey did not list factors that you believe are <u>always critical</u> to the success of any combat mission, please list them here.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Answer the questions 47 - 80 using the scale listed below:

1	2	3	4	5
Strongly Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Strongly Disagree

47. The Navigator/WSO/EWO is a critical resource on the airplane I am currently qualified to fly.

48. An aircraft designed to perform more than one type of mission should have a Navigator/WSO/EWO as part of the crew.

49. A Navigator/WSO/EWO would be useful in my squadron serving only in a non-flying capacity (i.e., an aid to mission planning, threat avoidance planning, and munitions employment planning).

50. I can perform my assigned wartime mission without a Navigator/WSO/EWO.

51. The addition of a Navigator/WSO/EWO to my airplane would increase the overall mission effectiveness of my taskings.

52. Technology will eventually replace the Navigator/WSO/EWO in the USAF.

53. Certain missions require a Navigator/WSO/EWO to be successful.

54. Certain missions I currently perform require a Navigator/WSO/EWO to be successful.

55. The Air Force is getting the desired level of mission effectiveness from the technology it purchases in its airplanes today.

56. Eventually, technology will replace the Pilot.

57. The Navigator/WSO/EWO is vital on night low-level, wartime missions.

58. A Navigator/WSO/EWO in my airplane would enhance the combat effectiveness of the factors I selected as always critical to mission success.

59. The training missions I fly now are adequately preparing me for combat.

1	2	3	4	5
Strongly Agree	**Somewhat Agree**	**No Opinion**	**Somewhat Disagree**	**Strongly Disagree**

60. The latest technological advances in US Air Force aircraft no longer require the Navigator/WSO/EWO to have a college degree.

61. The latest technological advances in US Air Force aircraft no longer require the Navigator/WSO/EWO to have the current amount of training now given at Undergraduate Navigator Training.

62. I would feel completely confident in my abilities to conduct a safe wartime mission if the Navigator/WSO/EWO were replaced with new cockpit automation technologies.

63. The Navigator/WSO/EWO can be essential during inflight emergencies.

64. New Cockpit Automation technologies incorporated into next generation aircraft should not replace crewmembers, but instead should enhance the effectiveness of existing crewmembers.

65. No matter how advanced the technology in any aircraft that performs my mission, there is a minimum number of aircrew members required to perform this mission.

66. The Advanced Tactical Fighter (ATF) should have a two person crew (a Pilot and Weapon System Officer).

67. A Navigator/WSO/EWO is required on some missions due to the complexity of the mission and pilot workload.

68. In combat aircraft, reducing operational costs by reducing the number of aircrew is more important than combat effectiveness.

69. It is possible, in my aircraft, to replace the Navigator/WSO/EWO with new cockpit technologies and maintain the same level of combat effectiveness.

70. In actual combat, I expect to encounter heavy fire and resistance.

71. Actual combat missions will probably be very similar to the training mission I fly now.

1 Strongly Agree	2 Somewhat Agree	3 No Opinion	4 Somewhat Disagree	5 Strongly Disagree

72. The combat missions I have flown were very similar to the training missions I flew prior to my combat experiences.

73. In actual combat, a Navigator/WSO/EWO would be critical to performing an effective mission.

74. The latest technological advances in US Air Force aircraft no longer require the Pilot to have a college degree.

75. The latest technological advances in US Air Force aircraft no longer require the Pilot to have the current amount of training now given at Undergraduate Pilot Training.

76. The Advanced Tactical Fighter (ATF) will eventually become a multi-role fighter.

77. Advanced cockpit technologies do not reduce workload.

78. Navigators/WSOs/EWOs and other aircrew members should be replaced if combat effectiveness is not reduced.

79. Navigators/WSOs/EWOs and other aircrew members should be replaced even if there is some reduction in overall combat effectiveness.

80. Navigators/WSOs/EWOs and other aircrew members should be replaced even if there is a large reduction in overall combat effectiveness.

B. Please feel free to make any comments about any of the topics this survey has covered. Use the space on the back of this page or attach additional sheets.

PLEASE PLACE THE SURVEY AND THE ANSWER SHEET IN THE ENVELOPE PROVIDED AND PLACE IN OUTGOING MAIL.

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

REPLY TO ATTN OF: LSR

3 June 91

SUBJECT: Participation in AFIT Research Survey Questionnaire

TO: Survey Participants

1. You have been randomly selected to participate in a very important research project sponsored by Air Force Systems Command's Aeronautical Systems Division (ASD). Your participation in this research effort is totally voluntary and anonymous. This research is concentrated in three main areas of interest: 1) Developing criteria that can be used to measure the effectiveness of a combat mission, 2) Determining the Navigator/Weapon Systems Officer (WSO)/Electronic Warfare Officer (EWO)'s contribution to the selected combat effectiveness criteria, and 3) Trying to answer the question of whether or not technology can <u>effectively</u> replace the Navigator/WSO/EWO in an aircraft performing combat missions. The accompanying survey represents the first time the pilots, the "users" of the hardware, have been asked for inputs on these topics. Your feelings and opinions will be used to help decide many of the features of the Air Force's next generation aircraft. Please read and follow the attached survey instructions, complete the survey, and return the survey and computer answer sheet in the provided pre-addressed envelope within 10 days of receiving the survey.

2. We want to take this opportunity to thank you in advance for taking the time to participate in this important research effort. If you have any questions or desire a copy of the survey results, please contact Dr. Kirk Vaughan, Maj Don Welch or Maj Kurt Starr, AFIT/LSR, DSN 785-2820.

Robert B. Weaver

ROBERT B. WEAVER
Head, Dept of Comm and Org'l Sci
School of Systems and Logistics

STRENGTH THROUGH KNOWLEDGE

Appendix B: Survey Comments

Introduction

The final question on the survey solicted comments from the respondents concerning the topics covered in the survey. The researchers did not ask for any specific information or give any guidance on specific topics to address. The comments reflect the respondents' desire to amplify or clarify their opinions about the subject matter of the survey. The quality and length of the comments reflect the time and care the respondents spent expressing their positions. The comments are useful for making qualitative judgements on the statistical data.

F-16

Twenty three percent of the F-16 pilots who returned surveys wrote comments.

1. Major, 501-750 F-16 flying hours, more than 3000 total flying hours, Instructor Pilot, Flight Evaluator:

> While I have been "single seat - single engine" for about four years now, I grew up with WSO's in the F-4 and was an F-4 WSO for my combat tour. While the F-16 is truly a dream machine and handles well as a one person killer, other aircraft (specifically F-15E and F-111) perform best with two crewmembers. Complex, low level, low visibility can be done single seat (witness LANTIRN) but is done better with two crewmembers.
>
> The theory that a "magic machine" can replace a man in an aircraft has been with us for a long time. Machines, no matter <u>how</u> "cosmic" are predictable and inflexible to planning changes-and therefore vulnerable in combat. A good man (or men) in their machine are still the most effective fighter.

The keys will stay the same: leadership, discipline, talent, dedication...and you can't program a machine for those.

2. Major, 751-1000 F-16 flying hours, less than 100 combat hours, 2501-3000 total hours, Instructor Pilot:

It pays to have an extra set of eyeballs and hands on-board these days. Depends on the mission and threat.

3. Captain, 751-1000 F-16 hours, 101-200 combat hours, 2001-2500 total hours:

I do not fly LANTIRN. I feel that units who fly LANTIRN should only fly LANTIRN and there should be only 4 to 6 squadrons and it should be only F-15Es with two people.

F-16's should have targeting pods and laser capability but should basically be DAY/VFR fighters that drop iron than go shoot people down. And it should remain single seat, single engine.

4. Lt Col, 1501-2000 F-16 flying hours, 101-200 combat hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

Combat effectiveness is essential especially in an Air Force reduced to 16 operational wings. Technology must be aimed not at replacing a crew member, but rather to enhance mission accomplishment. Once you optimize for the mission than you should evaluate work load on the pilot-now make a decision on a second crew member.

It is also important to remember the basic combat element is a four ship. Each aircraft does part of the mission. Four pilots work as a team. You have a synergistic effect. All aircraft need the same amount of capability, but the pilot's share responsibility.

5. Lt Col, less than 250 F-16 flying hours, 2001-2500 total hours, Instructor Pilot, Flight Evaluator:

I had problems answering some of these questions. The requirement for Nav/EWO/WSO's is driven by the same factors as our aircraft requirements-the threat and the mission. In a low threat environment, simple mission, a single seat aircraft does fine, e.g. A-10's in southern Iraq. However, high threat, complex missions will most likely require two-seat aircraft to get the kind of success we want, e.g. F-15E's at night against highly defended targets in Iraq. Stealth may be the answer vis-a-vis the threat; however, I wonder if a credible Iraqi air-to-air threat would have changed the outcome of F-117 operations.

In my opinion, the tough missions against the tough threats will always require a two-man crew for maximum result.

6. Captain, 501-750 F-16 flying hours, 1501-2000 total hours:

This survey assumes I would have a perfect WSO with perfect eyesight. This is not the case. A WSO not doing his job is far worse than not having a WSO. In a single seat fighter, at least I'm in control of my own mistakes. WSO management is not even addressed here.

7. Captain, 2510-500 F-16 hours, 1001-1500 total hours:

The F-16 would only be hampered by the 1300 pounds of fuel we lose. With the F110 engine-the BLK40 F-16-nothing can be too much drag to be ineffective. We've basically taken a 200 pound man and replaced him with 1500 pounds of Nav and targeting pods accounting for 53 units of drag. He would only add another 10-15 drag units. With the F-16's night mission -Spatial Disorientation becomes a prominent factor, especially in a jet known for Spatial D-a WSO could only be an asset in this demanding mission as I could concentrate on flying and he could concentrate on targeting. LANTIRN-two seat only!

8. Captain 251-500 F-16 flying hours, less than 100 combat hours, 1001-1500 total flying hours:

Combat effectiveness should never be sacrificed solely to save money!! Not only should degrees be required, but they should be in a technology field.

9. Major, 251-500 F-16 flying hours, less than 100 combat hours, 2001-2500 total hours, Instructor Pilot, Flight Evaluator:

I'm probably a poor choice to answer this survey having never flown an aircraft with an EWO/WSO/Nav. However, I do feel, having flown a lot at night in the F-117 and F-16E LANTIRN, that technology has brought us to the point where one man can do the job-low levels, attacks, survival, etc. at night. That's pretty impressive to me considering where we were 10 years ago. In my 12 years of flying, I've watched and flown the new technologies as they've come into service; and, in my opinion, one man can do the job. Do I ever wish someone else was with me? Yes, sometimes. There are some things out there that could be better performed if I had a second man on board. That doesn't mean I couldn't do it; just that I might have done it better, or more importantly, felt better about it and not had the pucker factor up so high. So bottom line, I don't believe I need an EWO/WSO, etc to perform my mission. In reference to #56, Yes, some technologies as witnessed in Desert Storm replaced the need for piloted aircraft, and that's good. I don't think, we'll get to a pilotless Air Force. If we go to an all technology concept without the human element-what will ever stop us from going to war? War, in my opinion, should have the human element-it will always ensure we think it out or stop it when the price in people is too high.

10. Captain, 1001-1500 F-16 flying hours, over 3000 total hours, Instructor Pilot, Flight Evaluator:

The only place for a WSO/EWO is in a wild weasel role using the F-15E! or the F-4G!

11. Major, 501-750 F-16 flying hours, 101-200 combat hours, 2501-3000 total hours, Instructor Pilot, Flight Evaluator:

I have flown the defense suppression mission for 3 years and have found through my combat experience that the EWO's in the F-4G were critical to the mission effectiveness. The technological systems are not good enough to distinguish between real and simulated threats, but the human being with a trained ear can make those critical distinctions. This was proven <u>many</u> times in the war with Iraq.

12. Major, 501-750 F-16 flying hours, 2501-3000 total hours, Instructor Pilot:

The F-16 obviously is combat effective without a WSO. In some aircraft I'm sure a WSO is important (i.e. F-15E). I have never flown with a WSO, but have seen pilots of other aircraft like F-15E's say they are extremely beneficial in Red Flag scenarios to handle work load, look out for threats, etc.

One advantage of F-16 is small size which would be somewhat compromised if enlarged for 2 aircrew-like the B or D models-too short on internal fuel for the combat effectiveness of the A or C. And less inflight rearward visibility than the A or C.

13. Captain, 251-500 F-16 flying hours, 101-200 combat hours, 2001-2500 total hours, Instructor Pilot:

It is my opinion that the driving force to eliminate WSO's/EWO's etc. is the personnel costs saved in doing so. It is also easier to meet desired mil specs for a single seat fighter than it is for a two-seater. Fuel and avionics are often sacrificed to add another cockpit to trainer variants of aircraft especially the F-16. Most single seat pilots like being alone in their jet. But on the other hand, an additional set of eyeballs and another brain would usually add to combat capability.

14. Captain, 751-1000 F-16 flying hours, 1501-2000 total hours, Instructor Pilot:

F-16's don't need WSO's. LANTIRN F-16's may consider WSO's for new MR/low time pilots-low level Nav at night w/mountains seems scary. F-15E's seem to do well with WSO's. F-117 w/hi tech don't seem to need WSO's (not forced into low altitude night low level nav).

15. Major, 501-750 F-16 flying hours, 2001-2500 total hours:

As a F-16C block 40 pilot, I feel absolutely positive I, as well as the rest of my sqd/wing, could successfully accomplish our wartime mission-decisively, and with minimal loss. As a F-4E pilot, I felt the same way, perhaps even more confident, given one factor-I select my WSO. For every successful, rewarding, and uneventful mission flown in the F-4, I can easily account for two to three times as many average to disastrous missions. Why? A lot of factors. The most predominate being: if I were just slightly more "ahead of the jet" than my WSO, he was a detriment to mission success. The time wasted to verbally catch the WSO up, or tell him what to do was usually at a critical phase of flight and time would have been better utilized if I could just do the task myself, i.e. hands on control in the F-16. Not everybody thinks the same way, and a lot can be overcome through crew coordination, but briefing on the ground and do in the air are two different things. I didn't have to fly with one of the best WSO's in the sqd. to get the right connection, but the WSO, however experienced/inexperienced, was a well educated, rational, and deductive thinker/crew member.

I guess the bottom line is-yes, with the "right connection/WSO" in the backseat of an F-16, our aircraft would be an improvement. I need an active member to not only do what I say or do as I do. But also as a pilot, I'm not willing to give up any control of systems in case the WSO is not up to the task. There was a lot a pilot could not do in the F-4 since most of the systems were run/operated from the back.

I believe low altitude missions are extremely demanding. Time management in the cockpit becomes critical. LANTIRN missions should be flown in aircraft like the F-15E or F-111. High threat CAS missions demand as much attention. Even with hands on controls, it was great to have a WSO input data and run the systems while I flew the aircraft. Perhaps a data link could do the same thing. Anyway, no matter how much a WSO could contribute to accomplishing the mission, it would just be more icing on the cake.

16. Major, 251-500 F-16 flying hours, 2001-2500 total hours:

The questions in this survey could lead to erroneous conclusions. I fly the F-16 without LANTIRN. The complexity and task intensity of F-16 LANTIRN and F-15E missions could well <u>demand</u> a second crew member. Mission accomplishment must remain inviolate or the military abolished. We must do the task correctly or not at all. I am a taxpayer and maintain cost consciousness.

17. 1Lt, under 250 F-16 flying hours, less than 100 combat hours, 501-750 total hours:

<u>Some</u> aircraft and <u>some</u> missions require 2-place cockpits but that doesn't mean that <u>all</u> missions and aircraft do. We need a follow-on weasel aircraft such as the F-15E with an APR-47 type RWR system. Air-to-air and air-to-ground missions alone do not require 2-place cockpits, but the weasel aircraft and night bombing aircraft should have 2. Although a trained LANTIRN F-16 guy can do it alone.

F-15E

Thirty six percent of the F-15E pilots who returned surveys wrote comments.

1. Major, 501-750 F-15E flying hours, 201-300 combat hours, 2501-3000 total hours, Instructor Pilot, Flight Evaluator:

> Q-49. Should be N/A for F-15E. We already have 30 plus WSO's and they don't do us much good unless we can fly them.
>
> Q-51. N/A F-15E.
>
> Q-56. With the increased Pk (Probability of Kill) of weapons, its possible that technology in that area will possibly replace the pilot/crew by increasing the risk of manned interdiction above acceptable levels. Drones have already been used in the are of RECCE and preplanned bombing.

2. Major, 501-750 F-15E flying hours, less than 100 combat hours, 2001-2500 total hours, Instructor Pilot:

> Q. "The WSO is a critical resource on the jet I fly."
>
> A. He can be, depending on the mission, and whether or not he's worth anything in the first place.
>
> This survey is not going to yield it's intended results because you're leaving out the human factor. If you want to know if WSO's should be replaced, just ask the question! Answer: No. If you want to know if WSO's should be replaced if it can be done with technology, the answer is yes. But, it can't be done, my friends. Technology cannot replace a pair of eyes that say "break right!" What you whiz kids envision and what is reality are two very separate entities. For example: We went to war with an ALR 56C and an ALR135 that were so full of bugs that they were worthless. If we had been up against someone besides those third world moronic ragheads, we would have lost a bunch of airplanes, and the pilots and WSO's that go in them.

3. Captain, 251-500 F-15E flying hours, less than 100 combat hours, 1501-2000 total hours:

> Every combat aircraft in the Air Force should have two

crew members. Anybody who says he can (by himself) fly in combat, while being shot at; possibly at night and at low level, while flying formation, avoiding threat and the terrain, run the radar and targeting systems, and visually search for incoming threats either doesn't understand the workload or has an extremely inflated self-opinion. To properly do any one of these things takes time, to do them all would be impossible.

Technology is great but cannot replace the backseater. If the backseater did nothing but sit and watch for threats he would be worth his weight in gold. Technology can give options, remind you of things you may have forgotten, or help you out when the systems are overloaded. A properly trained WSO is an asset to any weapon system. College educations and training (UPT/UNT) are required now more than ever. Technology is more than watching lights and pushing buttons. Without an understanding of the basics and theories you'll fall short when things start changing rapidly.

The saying "Two heads are better than one" applies here with full force. Two trained aircrew are better equipped to handle changing and dense threat environments better than any fighter with a single pilot, technology or not.

4. Captain, 251-500 F-15E flying hours, 101-200 combat hours, 2001-2500 total hours:

I can say this without any doubt: (from experience in Desert Storm in the F-15E.) Mission effectiveness and flight safety would be significantly degraded without the WSO. No matter how advanced the technology gets, someone will need to be heads down to look at it (to some degree), and who is clearing for a. lead; b. bandits (not using radar?); c. the ground; d. AAA; e. SAMS (heaters at least). Add night, low altitude, mission changes, etc. and it becomes more obvious that he is essential. Granted, on some missions I could have gotten by without the WSO, but these were the exception.

5. Captain, 251-500 F-15E flying hours, 101-200 combat hours, 1501-2000 total hours, Instructor Pilot, Flight Evaluator:

Desert Storm was the ultimate in battlefield flexibility, inflight targeting, etc. The more flexibility required inflight the bigger need for more than 1 person in an aircraft (ie one to fly, another to plan!)

Two sets of eyeballs will <u>always</u> be better than one!

Advanced cockpit technologies are great in peacetime/low threat arenas. The more complex the switchology, the easier it is to make switchology errors during high mission task phases of flight!

6. Captain, 251-500 F-15E flying hours, 1501-2000 total hours, Instructor Pilot:

Just another set of eyes (even with glasses) is worth it.

7. Captain, 251-500 F-15E flying hours, 101-200 combat hours, 1501-2000 total hours, Instructor Pilot:

Desert Storm (and to a lesser extent Vietnam) proved that multi-role (air-to-air and air-to-surface) capable aircraft (that are <u>adequately</u>) trained in the various missions the aircraft can accomplish will provide the air component commander with a versatile tool to accomplish the many varied and different missions required to win the battle(s) and then the war.

Critical to the success of a multirole fighter, is the crew concept pilot/WSO(EWO). Mission effectiveness and success are significantly improved, particularly in navigating to the target, negating threats, identifying the target, and successfully attacking the target, while minimizing losses. Lessons learned from Desert Storm:

1) Single seat (F-16's) were far (by a factor of 3x) more likely to "miss" their target and return to base with bombs unexpended, even with "new cockpit technologies." Reasons:

- New cockpit technologies did not provide the same increase of combat effectiveness that a WSO/EWO would provide;
- Pilot task saturation (threats) prevented target identification, hence the chance to attack and kill the target;
- Task saturation/pilot workload when the "tasking" was changed in the air (which was quite often) hindered single seat effectiveness.

Bottom line: 2 seats are a requirement for a follow on multirole aircraft.

8. 1Lt, 251-500 F-15E hours, 201-300 combat hours, 251-500 total hours:

> Task saturation and overload will continue to kill aircrew and destroy assets, no matter how much we improve technology. The only way I can see no need for a WSO/EWO is if we can guarantee weapon delivery launch and leave capability with no threat in target area to worry about. If any flexibility is required in the mission (like finding and destroying mobile scud launchers), then task management is required between two aircrew. My opinion is that the pilot needs to be free to optimize SA and aircraft handling for weapon delivery/threat avoidance while the WSO/EWO can apply the flexibility needed in delivering weapon on target and detect threats. Also, if we combine missions/roles into one aircraft, then we will have too many systems on board for one pilot to handle (radar, bomb guidance, lasers, chaff/flares, sensors, RWR, electronic warfare packages, etc) in the threat environment. I can't process an air attack, ground threats popping up, staying in formation, not hitting the ground and guiding a SMART bomb on target on a low-level night interdiction mission. The ensuing POW interrogation would be a bad result. Questions?

9. Captain, 501-750 F-15E flying hours, 101-200 combat hours, 2501-3000 total hours:

> I don't think there is a mission in the TAF that would not benefit from having a WSO in the aircraft. However I do understand operational cost and aircraft design that would make this impossible.

10. Captain, 501-750 F-15E flying hours, 101-200 combat hours, 1001-1500 total hours, Instructor Pilot, Flight Evaluator:

> There is not, and never will be a replacement for an extra pair of eyes. The ability to recall/refrag a mission is inherent to air power, especially occupied cockpits.

11. Captain, 751-1000 F-15E flying hours, 101-200 combat hours, 751-1000 total hours, Instructor Pilot:

Increasing weapon employment complexity, ie using the bombs, often dictates need for weapon operator especially under complex situations, second crewmember only critical during the critical 5% of mission. Decision making process can be aided by second person under complex conditions. As long as eyeballs are valuable four are better than two. Ref. Q76 - location of air to ground ordnance?

12. Captain, 501-750 F-15E flying hours, 101-200 combat hours, 2001-2500 total hours, Instructor Pilot:

Night, low level missions to a target that I fly as an F-15E pilot require a WSO for complete combat effectiveness. Some other missions/tactics do not require a WSO to carry out an effective mission, but threat detection is always enhanced by an additional crewmember and can spell the difference between a successful/unsuccessful mission. A single role mission such as the F-15C/ATF aircraft fly, in my opinion, do not require a WSO for total combat effectiveness. I would <u>not</u> want to fly an F-15E or even LANTIRN F-16 without one though.

13. Captain, 751-1000 F-15E flying hours, 2001-2500 total hours, Instructor Pilot, Flight Evaluator:

WSO's need to be flying! Tactical fighters should be 2-seaters-period!

14. Captain, 251-500 F-15E flying hours, 101-200 combat hours, 2001-2500 total hours:

Dual role fighters today, like the F-15E need WSO's to effectively handle their roles. During the war F-16's were not nearly as effective as we were and I believe that is partially due to the WSO along with the airplane itself. For people to handle the decisions required flying combat fighters, they need to be well educated.

15. LtCol, 751-1000 F-15E flying hours, 101-200 combat hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

I have flown single seat as well as 2 seat operational fighters for 17 years. I have flown every mission possible, except SEAD. I have also flown an exchange tour with the RAF. There is no substitute for a WSO in a fighter. After 47 combat missions in the Persian Gulf, I am more convinced than ever. Someone must always be looking outside while in enemy territory. You cannot use technology to replace the WSO or for that matter the pilot because of this. If you go single seat to save weight/performance/personnel costs (the bottom line), you will affect combat effectiveness, period, dot!

16. Captain, 501-750 F-15E flying hours, 101-200 combat hours, 2001-2500 total hours:

I am a very strong advocate of a two seat/two engine Air Force. I might have a semi-biased opinion, due to my F-4 and F-15E experience, but I think a WSO/EWO is a critical part of combat effectiveness in my current aircraft. I also feel that it would greatly increase the combat capability of the current single seat inventory! Not only does a backseater reduce the workload of the pilot and task saturation, he eliminates many common mistakes that occur during a mission. There is no technological advancement that can take the place of an aircrew member. As far as I'm concerned, in a fighter aircraft, two engines are always better than one, four eyes are always better than two and two heads are always better than one! I think my opinion stands strong and firm based on the results from operation Desert Storm.

17. Captain, 501-750 F-15E flying hours, less than 100 combat hour, 1501-2000 total hours:

In my seven years of flying combat aircraft in the USAF, I have not seen an issue that smoldered as much as the WSO/EWO/Nav issue. I firmly believe, simply stated, that the Air Force will make a tremendous mistake as they replace WSO/EWO crewmembers with "technology." Regardless of how great and automated we feel that our systems are, much, much more goes into flying in combat ready units than just sitting in the cockpit. Crews have to deal with planning, weather, night, adversity, and other flight members, etc. on training missions. In combat, I don't care how hard you've trained, or how ready you feel you are, when the enemy is shooting at you, and wants you dead, all of the technology and "office automation" in the world are not really going to help you. Another set of eyeballs; someone running the radar looking for bad guys as we fly at low level at night or someone guiding precision guided weapons while you get the hell out of the target area is what makes a combat aircraft survivable, effective, reliable, on time, on time over target and accurate. In my opinion, there is not a single seat aircraft in the USAF inventory today that would not be 100% more effective with a WSO/EWO in the rear cockpit.

18. Major, 751-1000 F-15E flying hours, 2700 total hours, Instructor Pilot, Flight Evaluator, Weapons & Tactics Officer:

With current technology in today's Dual or Multirole Fighter, delivery of PGM's requires a 2 seat fighter. Should the software by improved to the point where the pilot can acquire and track the target with targeting pod then there would be no need for a WSO. In the F-15E, the only time I need a WSO is in the delivery of PGM's as stated above. I believe we are not far from the time they can be replaced. The F-117 can do it (PGMs) now without WSO's; however, there employment is rather benign-medium altitude/night nonmanuevering.

The second man in the fighter cockpit, more times than not, places more demands and taskloading on the pilot. Frequently the most difficult task is crew coordination with the WSO. Items such as when to talk and when to listen, duplication of efforts, etc... I suppose the bottom line is let's get the technology to do the second man stuff to reduce workload so the pilot can concentrate on pilotage skills and tactics.

19. Captain, 501-750 F-15E flying hours, 301-400 combat hours, 2001-2500 total hours:

With current technology and systems integration, a second crewmember is essential to perform all missions well. You could not replace him in F-15E without a very large reduction in combat effectiveness. As more capable, reliable and automated navigation targeting systems become available, I believe this will change somewhat. The backseater's second pair of eyeballs will <u>never</u> be replaced however. The ability to always have one or the other always clearing outside was the <u>most</u> valuable asset for survivability in combat.

No matter how advanced technology becomes, some amount of heads down time is required (inputting coordinates for tgt changes, etc). The ability to share these duties <u>always</u> insures visual lookout for unguided AAA or IR Sams. When you employ mostly at night, you have to check your own six as a wingman due to a traintype formation, making a back seater even more valuable.

<u>KC-135</u>

Twelve percent of the KC-135 pilots who returned surveys wrote comments.

1. Captain, 1001-1500 KC-135 flying hours (also total hours):

I had difficulty with how #16-46 were worded. There are a lot of "depends" because of the way it is worded.

16. Aviators <u>need</u> the ability to fly in adverse weather incase there is adverse weather. Whether or not it is critical to mission success depends on the weather. (The question could be worded better.)

17. How much mission planning is necessary varies from pilot to pilot. Some pilots grasp some missions faster than other pilots.

18. Need to monitor on-board avionics/weapons. If no malfunctions it's not a problem. If there's a malfunction and it's caught, it might be solvable and it might/might not be a problem. If it's not caught, it might/might not be a problem (depending on the problem), but it's more likely to pose a problem to the mission since it can't be fixed/overcome it it's not known.

19. You must not do something stupid (unsafe) which would jeopardize the mission, but sometimes you need to take risks to ensure mission success.

20. Depends on which equipment degrades.

31. Depends on enemy's defenses.

32. Depends on which crewmember.

34. Would be critical if there's a mission change.

35. Good crew rest requires good facilities (noise control, temperature control).

40. Need the ability in case other equipment fails.

41. Need the ability if flying at night.

42. Might need the ability if threats threaten survivability at low speeds.

43. Need to know where you are!

46. Terrain avoidance is critical; terrain following may/may not be.

49. That's what training flight Navs are for, or the Nav positions in DOX (OPS/INTEL/PLANS) and DOND (unusual or HHD missions)

59. We do not currently have threat detection capability on the aircraft. We do not generally practice threat avoidance or withdrawal procedures if a threat is detected.

62. Equipment fails far more often than people.

78. But how will you know if combat effectiveness is not reduced? I think having a Nav/WSO on board almost always enhances mission effectiveness.

79. Depends on aircraft. How much is effectiveness reduced? How important is the mission?

2. Captain, 501-750 KC-135 hours (also total hours):

Since I fly the KC-135, I do not log combat time, so references to combat flying are not apt. I logged 80 hours of combat support time in Desert Storm. Answers to "combat" questions were made with that experience in mind. It is also important to note that the conventional contingency faced in Southwest Asia is by no means the only "combat" or wartime environment we in the tanker field will face. Most of our training and preparation is aimed at strategic deterrence and for this role the navigator is absolutely essential. I have no useful opinion on the impact of WSO's in fighter or bomber aircraft. Faced with a nuclear war rather than a conventional one, however, the deletion of the navigator would be a grave mistake. All of the factors which I found to be critical or almost always critical to mission success are enhanced by the presence of a well trained intelligent navigator, not just a button pusher but someone who knows what's going on. I marked that I "somewhat agree" that a navigator should be replaced if combat effectiveness will not be affected, if money can be saved, but I do not think this is possible across the entire spectrum of missions we in tankers are expected to be able to accomplish.

3. Captain, 1001-1500 KC-135 hours (also total hours):

As I flew only combat support sorties, it is very difficult to comment on combat oriented questions. Reference necessity of the Nav in the KC-135: The Nav is essential with existing cockpit equipment. Place a color radar, double INS, and/or GPS in the cockpit and we don't need a Nav.

4. LtCol, over 3000 KC-135 flying hours, 101-200 combat hours, over 3000 total hours, Instructor Pilot, Flight Evaluator, Wing Weapons & Tactics Officer:

#51. I was unsure of what the addition of a navigator to my airplane would include. Does that make 2 navigators for the KC-135? I put no opinion, however, if I was supposed to assume I didn't already have one the addition of one would be very important.

#78. I reluctantly answered somewhat agree. I feel it's a bad question because I don't feel it's possible to replace the Nav and not reduce combat effectiveness.

In general I would say the Nav on the KC-135 is a vital crewmember. During Desert Storm, the Nav was very important. He kept us on station and steered us through the maze of flight routes while the pilots kept their eyes open for traffic and enemy aircraft. He was vital to our mission effectiveness. Even in peacetime the Nav is very important. The extra set of eyes and ears has saved our rear ends more than once. Just ask any tanker crew. There's nothing like being required to maintain orbit in a tiny box in 100 knot cross winds, where straying from the box could mean a mid-air collision or being shot down, to convince someone that you need a full time crewmember keeping an eye on your position. Same with combat departures-350 knots, 200 AGL, at night in a tanker with no low level equipment. It takes 2 pilots and a Nav-minimum!

4. LtCol, over 3000 KC-135 flying hours (also total hours), 401-500 combat hours, Instructor Pilot, Flight Evaluator:

The KC-135 can be operated in wartime without navigators on board if modern technologies such as additional INS or Global Positioning System (GPS) equipment is added. KC-10's with triple INS have no navigators yet they performed some of the toughest missions over enemy territory during Desert Storm. We need to get modern navigational systems installed and replace the navigators-their job has been rendered obsolete by technology.

5. Captain, 501-750 KC-135 flying hours, 101-200 combat hours, 2000-2500 total hours:

Some types of missions will always require a navigator, specifically, night or day low altitude air refueling. The reason is that one pilot is busy flying the airplane, the other is keeping the CG within limits while transferring fuel so you need a third person that can concentrate on course and timing requirements. At higher altitudes the pilot flying the aircraft can assist in the offload or navigation because terrain avoidance is not as critical. In Desert Storm, we refueled fighters as low as 4000 feet and others in my unit refueled at night <u>without</u> special NVG's as low as 2000 feet AGL.

#50. With the technology currently available on the aircraft, 1950's/60's technology, this mission cannot be performed without a navigator. With the technology that most modern aircraft have, specifically dual INS with laser ring gyro's, this mission could be performed without the navigator but would require additional training of the pilot team in order to handle the workload.

#70. In this aircraft during Operation Desert Storm, we were tasked to refuel two fighters deep into hostile territory, threading our way through SAM and AAA sights. The navigation aid we used was a single INS built in the mid-1960's with a circular error permissible to over 6NM for the time aloft. We were unable to use any other navigation means because of emissions control (Doppler, Radar, etc.) The distance between the threat rings was sometimes less than 2NM. We were plain lucky that the enemy didn't know how to employ his equipment. Our receivers could update their INS's on known ground landmarks, but we do not have the instant update capability. As far as airborne threats, again we were very lucky our enemy was inept or else there would have been <u>many</u> tanker losses. Several tankers were fired upon by both AAA and SAMs but were either out of range or just lucky as one of our crews was when a SAM exploded 1NM off his nose at his flight level!

6. Captain, 1001-1500 KC-135 flying hours (also total hours):

Cut costs by reducing other waste (flight schedules, O-6's). Reduce waste, not men\effectiveness.

They are critical part of team. They earn their keep during every mission change inflight. (They know our capabilities for scheduling changes) Mission deputy commander.

7. Captain, 751-1000 KC-135 flying hours (also total hours):

I feel there are certain technologies that need to be placed on the tanker fleet, not to mention we need to start looking for a replacement aircraft now! The present configuration of my aircraft requires that we have a navigator; it's impossible without him at this time. I have flown in Operation Desert Shield and believe me, we would have been severely degraded without the navigator due to cockpit configuration and lack of avionics.

8. Major, 1501-2000 KC-135 flying hours (also total hours), Instructor Pilot, Wing Tactics Officer:

Adding high technology components to current weapon systems has the potential to greatly increase workload if not properly integrated. For example, the FSAS system in the KC-135 was a case of putting modern technology in an old aircraft and only doing part of what is required to make it work efficiently. New technology like the Boeing 757 is a good example of well integrated technology.

A-10

Twenty one percent of the A-10 pilots who returned surveys wrote comments.

1. LtCol, 1001-1500 A-10 flying hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

I have always been a single seat aviator...A-10, F-117A, and the A-7E with the U.S. Navy. I'm sure I am not a reliable source for "crewmember" questions. I can only give opinions. You would expect me to be quite parochial, but here's my bottom line...A 2-man fighter crew will enhance the combat effectiveness of any fighter. That is the question, is it not??

2. Captain, 751-1000 A-10 flying hours, 101-200 combat hours, Instructor Pilot, Flight Evaluator:

> What about 2 pilots with one acting as an Aircraft Commander? It works in non-tactical aircraft.

3. LtCol, 2001-2500 A-10 flying hours, less than 100 combat hours, Instructor Pilot, Tactics Officer:

> The A-10 will never perform reduced threat-brush fire war close air support. There will always be fighter pilots because you can never replace the man-in-the-loop with remote controls.

4. LtCol, 2001-2500 A-10 flying hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

> For the foreseeable future (next 20 years), I believe the Nav/WSO/EWO will only be a vital part of air to surface tactical team. The threat presented in the air to air arena can be handled by our present systems. However, the requirement to employ at night in an integrated air defense capability (IADS) requires a much more demanding capability on our part.

5. LtCol, 1501-2000 A-10 flying hours, less than 100 combat hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

> Crew tactical fighters have a place in multiroled aircraft for workload reduction in high task situations. However it's not needed in close air support roles.

6. Captain, 2001-2500 A-10 flying hours, less than 100 combat hours, Instructor Pilot, Tactics Officer:

> This survey really should not be given to pilots who have never flown two seat fighters, ie A-10 pilots. I truthfully have no grasp of how much a WSO would help. I have always heard how much two sets of eyes help in air to air but I have always done well against F-4's especially and equally so against F-16's and F-15's. Question 69: I did not answer because my aircraft does not have a WSO.

7. Major, 251-500 A-10 flying hours, less than 100 combat hours, 2001-2500 total hours, Instructor Pilot:

> Two-place fighter vs. single-seat is a complicated issue. It would be desirable to not have WSO's/EWO's in the fighter community because they are regarded as second class citizens. If we were all pilots, then part of our "us and them" problems would go away. Please note that I did not say they are second class citizens - just that they are predominantly perceived as such and that distinction is not good for our business. Having said that, you can easily come up with a scenario where 2 sets of eyeballs will be better than one. If you have a large airframe (such as the Strike Eagle), it probably doesn't make sense to make it a single-seater when all you gain is empty space for baggage. If you have a small airframe (F-16) that can do the job with technology, then don't make it bigger just to put two-seats in it. I would recommend that logic for future aircraft as well.

8. Captain, 1001-1500 A-10 flying hours, less than 100 combat hours, Instructor Pilot, Flight Evaluator:

> This was a little difficult since I am an A-10 pilot and have always done it all by myself. I don't think WSO's are essential to accomplishing any mission. I think certain aircraft were designed so that 2 people are required to get bombs on target. Example: Single seat F-117's could have probably done the raid on Lybia just as well as 2-seat F-111's. Therefore, I think the design of the aircraft systems dictates whether a WSO is needed or not. I have no idea why a C-130 needs a navigator; what are the pilot and co-pilot so busy doing that they can't figure out which way to go. In summary, I don't believe Navs are essential in general.
>
> I will admit, however, there have been times when a little help or an extra pair of eyes would have been nice, but I don't think we can afford the extra expense in today's shrinking AF. Get rid of all the WSO's and keep an extra A-10 squadron in service. And yes, maybe someday we can build awesome aerial machines that won't need pilots. I guess we already have those though. They call them missiles I think.

9. LtCol, 1001-1500 A-10 flying hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

> Tough to answer some questions, since A-10 never had a

Nav/EWO/WSO. Also, on #71 & 72, tough to answer yes/no. I felt actual combat would be like training sorties, but since I was in the 1st all night A-10 squadron the actual sorties were different than training, since normal training was day sorties and maybe 6 night sorties every 6 months. But all my combat sorties were at night so in that respect it was not like how we trained.

10. Captain, 1501-2000 A-10 flying hours, less than 100 combat hours, 2001-2500 total hours, Instructor Pilot:

I think new cockpit technologies will not reduce cockpit workload because they will allow more information to be displayed to the aircrew. I believe that training in both UNT and UPT will have to be increased to adequately prepare aircrews for the more advanced and complicated cockpit technologies being developed because of the information overload they will cause.

I do not believe that a college education necessarily shows any aptitude an individual may have to be a pilot or navigator. Many people who do not have a college education have the mental capacity to be a pilot or navigator and many people with college educations do not. It is just one discriminator of many to see if someone is capable of performing aircrew responsibilities. If there were accurate tests to measure mental capabilities they could be substituted. But piloting or navigating an aircraft also involves physical abilities and it is very hard to pretest for the required mix of mental and physical capabilities you have to start somewhere.

11. Major, 1001-1500 A-10 flying hours, less than 100 combat hours, 2501-3000 total hours, Instructor Pilot:

Questions 47-80: Currently I'm an A-10 pilot. I have also flown the F-5 stateside and overseas. The topics covered in questions 47-80 were extremely difficult to answer in part because I've never flown with a navigator or WSO. By responding to some of those questions, I hope your survey doesn't get tainted. It may be beneficial to add a response to your answers like instead of "no opinion" "Only flown single seat A/C."

12. Captain, 751-1000 A-10 flying hours, less than 100 combat hours, Instructor Pilot:

As I am an A-10 pilot, my experiences with the crew concept are nil, however I do have my opinions. I believe WSO/EWO/Navs are vital for certain reasons. For example, the F-15E, F-111, B-1, B-52. I do not believe technology can ever replace the judgment of a man. I also feel that technological advances do not necessarily reduce aircrew workload. Some do, some don't, some advances foster dependence on machines that aren't always foolproof. I think that asking one man to be proficient at a variety of missions, ie the F-16, overtasks the abilities of the pilot so that he is adequate in all things, but good at few things. I believe multi-role fighters need WSO's for that reason. Cost should never be a factor in combat readiness. You get what you pay for.

13. LtCol, 751-1000 A-10 flying hours, less than 100 combat hours, 2501-3000 total hours:

Technological advances <u>may</u> minimize workload if man-machine interface is engineered properly. If not, it may transfer workload to noncritical parts of mission, which is good, or increase workload at critical times, which is bad! Key is <u>design</u> and testing with real people. My flying time is all in single seat fighters and ATC, so I'm not an expert, but I think some traditional Nav functions could be handled by NCOs. EWO/WSO should stay officers.

14. Captain, 1001-1500 A-10 flying hours, Instructor Pilot:

Most of this is N/A for a-10 pilots. I have never flown operationally with a WSO/EWO nor have I ever talked to one about his job or importance.

15. Captain, 251-500 A-10 flying hours, 1501-2000 total hours:

1. We must have a balance of numerous, inexpensive fighters and the few high-tech marvels we can afford.

2. Mission effectiveness must never be reduced in an individual airframe. It must be tailored to provide flexibility to the pilot/aircrew, i..e., gun system built in. This is because we are going to have less total aircraft.

3. In MAJCOM-specific regulations covering weapons delivery (USAFER 51-60) manual systems have a smaller CEA for qualification than some automatic delivery systems. Are we paying more $ for bombs further from

the target?

4. We need good target identification friend or foe and some way to point out the target for our pilots (SA).

B-52

Twenty one percent of the B-52 pilots who returned surveys wrote comments.

1. Captain, 1001-1500 B-52 flying hours:

> The B-52 is quite antiquated, and I feel the cost of removing the EWO with updated technology costs too much to make it worthwhile. Our workload on the B-52 is incredible and it's a necessity to have the defensive stations manned.

2. Captain, 3000 B-52 flying hours, 101-200 combat hours, Instructor Pilot, Flight Evaluator:

> An overemphasis on technological systems may backfire if we're not careful. I'm sure, eventually, that systems may eventually replace the human element in certain aircraft. But, I don't believe we've developed the necessary reliability required to place all of our trust into something that may mean the difference in the continuance of the US, it's government, and it's people. The human operators provide a redundancy and adaptability that, I believe, automated systems don't have.

3. Major, 1000-1500 B-52 flying hours, over 3000 total hours:

> The advances in technology and avionics which have been incorporated into the B-52 over the past 16 years in which I've flown it have greatly enhanced its capabilities and effectiveness. Though not having flown actual combat sorties, I've flown every type of mission capable in this aircraft-including Desert Shield sorties in the same combat environment as Desert Storm-one thing concerning Navs and EWOs is always true: They probably could be replaced by technology as long as <u>everything</u> works as intended and the mission goes as planned. I've helped introduce EVS, FLIR, Phase VI ECM, SRAM, AOU, OAS and ALCM to the Buff. I've dropped MK72 and 84 weapons, and launched actual SRAM and ALCM missiles. In all cases, the human

element operating the systems, manually working around problems when the automatic features failed/malfunctioned were what continually made effective missions out of potential aborts. In a high threat environment, B-52 pilots are saturated with workload of flying the aircraft. Navs/EWOs are essential. Similar thoughts apply to the B-1. Don't eliminate these vital crewmembers, rather use technology to make them more effective and alter UNT training towards effective understanding and use of current equipment.

4. Captain, 1001-1500 B-52 flying hours, 1501-2000 total hours:

Advances in technology can ease the workloads for aircrews, As can be seen with the evolution of aircraft, i.e. B-52, B-1, B-2 or F-4 - F-16. Depending on the complexity of the mission, aircrews could be reduced with an increase in technology. Fighters appear to be able to function quite well with only one crewmember, on the other hand complex tasks (low level, night, mountainous, weapons delivery) require more than one crewmember. One crewmember to fly, the other to deliver the weapons. In the B-52 the advances in computer assisting have made "conventional" Nav's obsolete. Being a former EWO it is obvious computers are replacing hands on operators, but they can't be replaced all together. Solution EWO/WSO/Nav all rolled into one.

5. Capt, 751-1000 B-52 flying hours, 2501-3000 total hours:

The aircraft I currently fly is sufficiently old (despite upgrades) and the mission complex enough that at least one offensive crewmember (RN/NN/OSO) and one defensive crewmember (EWO/DSO) should be included to handle mission changes, equipment degrades, and defensive countermeasures as the need arises. Newer aircraft and systems may be reliable enough that in a threat-free environment, the human operator is unnecessary, but in combat the human will always be required for all but the most basic missions.

6. Captain, 751-1000 B-52 flying hours, 1501-2000 total hours:

I'm sure that someday, if not today, technology will replace not only Nav/WSO/EWO but pilots too. Unfortunately machines are not 100% reliable and relying solely on machinery and computers to accomplish a combat mission where human lives are at stake seems ludicrous!

7. Captain, 751-1000 B-52 flying hours, 1501-2000 total hours:

A WSO in a fighter type aircraft should be there to "check six" and provide another set of eyeballs to enhance visual lookout. In a heavy low-maneuverable bomber, technology could probably replace a Nav/EWO, since you can't maneuver much or visually clear the back of the aircraft.

8. Captain, 751-1000 B-52 flying hours, 1001-1500 total hours, Instructor Pilot, Flight Evaluator:

With the current level of technology available for automated EWO/Nav duties, I would not feel comfortable going to war (ie B-1 problems). I could possibly see having only 1 offensive and defensive person, but never a totally automated system. In reference to questions 70,71, recent experience showed that B-52 mission profiles in training were not consistent with what was actually flown in combat. What I expect to experience and what actually may be experienced in combat may be completely different, but I'd rather train for the worst scenario and have it be a milk-run than vice-versa.

9. Captain, 751-1000 B-52 flying hours:

In the B-52H, the navigator and radar are essential (especially during a combat mission) only because the technology makes them so. In the Iraq war, the GPS loaded on the "G" models made the radarnav obsolete. The copilot could easily handle an INS system reliable enough not to need too many updates. So I do believe that automated systems could easily replace current crewmembers. Is it worth it for the Buff? There's another question-I'll leave it to you.

10. Captain, 1001-1500 B-52 flying hours:

The B-52 has very little "advanced technology" in the cockpit. It is hard to place value on these "systems" vs. a navigator, bomber-radar, EW when we don't have the two to compare. My opinion is that no mission should be flown with less than two aircrew members. Having another set of eyes in the cockpit is always a good idea. Compare F-4 accident rates/types to F-16 accident rates/types. You'll find that a backseater not only increases combat effectiveness, but also helps reduce loss of Air Force assets to accidents.

The B-52 with current modifications is unable to fly its mission without a navigator rated person on board. Our ECM is hand operated by the EW. Also education of pilots and navigators in a college environment is essential to ensure an intelligent and professional cadre of airmen in the Air Force.

11. Captain, 2001-2500 B-52 flying hours:

#66: ATF's should have a two-person crew to share the workload and improve safety. Today's single-seat fighters are highly task saturated and highly susceptible to pilot error as proven day after day by the large number of fatal mishaps that occur. Multiplace aircraft have maintained a much better safety record, while still being exposed to a high threat environment.

12. Captain, 501-750 B-52 flying hours:

The cost of training and paying a navigator is extremely little when compared to the cost of some of our new, modern warplanes. Cost of having a navigator should be a small factor in deciding whether navigators, EWO's are needed.

In the B-52, the navigator is an extremely important position (although I do not know if 2 are needed). The EWO could probably be replaced by modern ECM equipment.

I feel with the cost of our new weapon systems, it is asinine not to have 2 people in the cockpit working together and backing each other up.

13. Captain, 1001-1500 B-52 flying hours, less than 100 combat hours:

Heavy bombers (B-52, B-2) require at least two pilot crewmembers to reduce workload or flying 10+ hour missions, even with functional autopilot.

14. Captain, 751-1000 B-52 flying hours, less than 100 combat hours:

Your questions about technological advances replacing crewmembers are not valid when the survey participant is unaware of the advances you refer to. I'm sure some can replace a crewmember, but in my aircraft I know that each person is very vital due to excessive workloads which can be created during attack or emergencies. I believe that the reasoning power of a human is more valuable than all the workload reducing devices. The technology the Air Force is receiving today seems to fall short of the money spent for it. It is usually built by the lowest bidder to meet a skeleton of specifications to perform the task to a mediocre degree of completion. If our country, liberties and lifestyle is worth defending, then our defenders should receive equipment that is the best not the least expensive.

15. Major, 2501-3000 B-52 flying hours, Instructor Pilot, Tactics Officer:

Questions 16-46 were very difficult to give a single answer to. The B-52 EWO mission is our primary mission with a given set of parameters. Conventional missions have a very wide range of mission types, targets, delivery tactics and most importantly defensive environments. Several statements would range from vitally critical to not even a player depending on the mission.

Technology is a wonderful thing. When you automate the aircraft, you now have a different version of a guided missile-not a plane where the human element can adapt to the given situation (which in combat is never what you expected). When the systems are working as advertised, and nothing unusual/unexpected occurs, automated systems can reduce the workload of a Nav/EWO considerably, but system failures (partial to total) and last minute changes/use of wartime modes can best be handled if there is a crewmember there.

16. Captain, 1001-1500 B-52 flying hours:

No machine can replace a nav in combat. Since the machine must be operated by a crewmember, the crewmember would divert attention away from overall situation awareness in order to operate the equipment. Also, the nav can think and plan ahead, something I doubt even artificial intelligence computers could do adequately in an ever changing combat environment. I do not believe you could remove/replace the navigator without reducing combat effectiveness.

17. Captain, 1001-1500 B-52 flying hours, 101-200 combat hours, 1501-2000 total hours:

> This whole issue about taking crewmembers out of aircraft is ridiculous. You need to have the human factor in the loop. If not, and the machine fails, a serious problem can result. I feel technology can <u>never</u> replace the human!

<u>C-130</u>

Twenty eight percent of the C-130 pilots who returned surveys wrote comments.

1. 1Lt, 1001-1500 C-130 flying hours, less than 100 combat hours:

> Overall, a navigator is currently required in the airplane I fly and the missions I may be tasked to accomplish. I feel automation and technology can replace the navigator in a tactical airlift airplane. The equipment found on my aircraft is far behind that found on today's commercial transports and modern fighter aircraft. With a good mix of equipment found on those aircraft, I feel the C-130 can be made a much more effective weapon system even without a navigator, such as in the proposed C-130J. I also feel, even the engineer can be replaced with a modern aircraft systems design. Even though I feel a navigator i[illegible] unnecessary in a properly equipped aircraft, I feel [illegible]SO, EWO, or at least an additional crewmember is es[illegible]al in fighter aircraft. An additional crewmemb[illegible] on those type of aircraft can share the workload and <u>more importantly</u> is another set of <u>eyes</u>.
>
> Those crewmembers involved in a leadership position in the aircraft and squadron should all be officers. Navigators need not be officers, but they must be college educated. I feel a college education enhances one's <u>basic</u> abilities to comprehend, retain, and analyze which is necessary when dealing with today's modern equipment and not just any college education, but an education that's based on math and science. I feel at an advantage over my peers with my education in aeronautical engineering.
>
> I hope my comments help in your research. Thanks for your concern with tomorrow's Air Force!

2. Captain, 2001-2500 C-130 flying hours, 101-200 combat hours, Instructor Pilot:

> Many of these questions deal broadly with very aircraft/mission situational areas. (i.e. - some aircraft have missions where the Nav/WSO/EWO is absolutely essential - C-130 airdrop operations are one example - other missions and aircraft probably do not require the extra man in some cases).

3. Captain, 751-1000 C-130 flying hours, less than 100 combat hours, 2501-3000 total hours, Instructor Pilot:

> The navigators I've flown with both in training and during actual combat sorties have proven their worth time and again. I doubt there is any technology available today, or in the foreseeable future, that would possibly replace our Navs.

4. LtCol, more than 3000 C-130 flying hours, less than 100 combat hours, Instructor Pilot, Flight Evaluator:

> Only human pilots and navigators have the flexibility to adapt to the changing requirements and dynamics of combat. Technology helps the crewmembers but we cannot develop the exact system required for an uncertain future. Develop good reliable equipment that is adaptable then train the crews to use it!

5. Captain, 751-1000 C-130 flying hours, less than 100 combat hours, 1501-2000 total hours, Instructor Pilot, Tactics Officer:

> I feel it is important to retain navigators/EWO's even with the advent of advanced navigation technologies to avoid pilot task saturation, and to assure mission tasking flexibility. Navigation computers work fine when the mission is proceeding as planned, but with in-flight refrags, bad weather, unexpected threats to avoid, etc., the navigator is indispensable in modifying the plan, reprogramming the computer, and thinking of items the pilot may have very easily overlooked while he's busy flying. Keep the navigators!

6. Major, more than 3000 C-130 flying hours, Instructor Pilot:

I strongly believe that a navigator is essential to successful wartime mission accomplishment in my aircraft. My choice with increasing technology (such as in the C-17) would be to have a navigator with minimal pilot skills (to help fly during emergencies or injuries) instead of a copilot with minimal navigation skills doing the bulk of low level chart reading and navigation. Suggestion: Navigators on TAC airlift/airdrop/airland missions and copilots on strategic airlift missions (mainly as a way for copilots to gain aircraft systems and operations experience prior to becoming aircraft commanders).

7. LtCol, 2001-2500 C-130 flying hours, more than 3000 total hours, Instructor Pilot, Flight Evaluator:

Having flown EC-130's (compass call) as well as TAC airlift C-130's, the role of the nav as well as the EWO play a vital role in mission accomplishment, no matter how good the technology is. If by some chance the USAF is thinking of reducing its nav force, why not allow these experienced aviators the opportunity to go to UPT to enhance their careers, and perhaps give someone a chance who has air-sense and knowledge of the system, instead of some snot-nosed ROTC-OTS puke that doesn't know a stick from a rudder? Perhaps less wash-outs and a better quality pilot, thus saving those ever blessed congressional funds.

8. LtCol, more than 3000 C-130 flying hours, 501-1000 combat hours, Instructor Pilot, Flight Evaluator:

A third professional airman is of great value on the flight deck during flight/ground ops. Most of the time we're not in combat but we're vulnerable to many hazards in the flight environment. We do not have the experience or the corporate support to train to every airfield we go into or area we fly. The third airman is often the voice that drives a decision one way or another. Our aircraft commanders are performing to the degree that their capabilities allow. Those not so strong are teamed up with strong navigators in some cases. Our crew force is young and relatively inexperienced, but survives well with an individual who isn't at a set of controls and can see the big picture. Sometimes we load that individual too heavily with crew duties (i.e. C-130 AWACS navigator) - technology could help this individual but not replace him.

A college degree has a lot to do with being an officer-little to do with flying. Marine C-130 nav's are/were?

enlisted.

The C-17 could fly some missions with no nav. High altitude to a benign peacetime destination should be OK. Other times a nav should be part of the crew. Suggest a flight deck area be available with wiring for plug in avionic's on newer aircraft. Snap in additional readout/control leads for the nav when that crew member is needed.

9. LtCol, more than 3000 C-130 flying hours, 75 combat hours, Instructor Pilot:

#72. Desert Storm missions were easier than our training missions. Unfortunately they did not reflect the skills required in total war with a competent enemy.

#52/69. With SCNS C-130s the pilots could be trained to do the nav's job.

#74. Perhaps an associate degree in aviation technology.

10. LtCol, over 3000 C-130 flying hours, less than 100 combat hours, Instructor Pilot, Flight Evaluator:

There is more than just combat effectiveness to measure mission success. The navigator is essential to safety. Enhance the mission with or without technology advances.

11. Captain, 1001-1500 C-130 flying hours, 1501-200 total hours:

There are many tasks which technology can do better than a navigator but having a man who can think and reason when the equipment breaks is an irreplaceable asset and very much needed when judgment is required to complete the missions.

12. Captain, 1001-1500 C-130 flying hours:

To questions concerning navigators: C-130's will no longer need nav's for airland missions but no electronics can replace a nav on low-level airdrop and austere airland missions, day or night. Some multilateral airdrop JA/ATT's can do without a nav as well. But, bottom line, the wartime mission will be seriously effected without a nav.

13. Major, more than 3000 C-130 flying hours, Instructor Pilot, Flight Evaluator:

> Although modern avionics systems work wonderfully, they can't think, improvise, or handle the unexpected. Seldom in war do things go "as expected." If we design our new airplanes around one and two-man crews in the cockpit, we will sacrifice flexibility and mission accomplishment. If anything, the amount of information available in modern airplanes argues for more navigators (or systems operators. or whatever you wish to call them). That we saved 770 million dollars personnel cost over the life of X weapon system will be cold comfort if in doing so we contribute to our defeat in a war. Obviously, I don't think "black boxes" are a very good replacement for the two eyes, two ears, and brain of a trained and experienced crewmember. As a tax payer who will retire soon, I would like to save defense money as much as the next citizen. However, we should be aware of "false economies."

14. 1Lt, 751-1000 C-130 flying hours, less than 100 combat hours, 1001-1500 total hours:

> The C-130 aircraft has proven itself time after time as being essential to combat support operations. I believe this is due to the aircraft's capabilitites as well as the crewmembers' capabilitites & ability to work as a team. The navigator is essential to this aircrew effectiveness. I believe that advanced technology is an excellent addition to the C-130 mission (AWADS, PINS, SCNS, etc.) and is needed to reduce crewmember workload. However, I also believe that the human factor is essential in completing the mission successfully. With technology and crewmember interaction, I feel the mission effectiveness is greatly enhanced.
>
> Advanced technology is essential to the C-130 mission as well as aircrew interaction. Together, the team can work successfully & effectively. I do believe that in the C-130, a navigator will always be needed.

15. 1Lt, 751-1000 C-130 flying hours, less than 100 combat hours:

> The C-130's mission, as presently stated, relies quite heavily upon a navigator's performance. Regardless of the modernization of the aircraft's avionics, I do not foresee the elimination of the navigator as a primary

crew member. Nor would I relish the opportunity to enter a combat environment w/o at least one navigator on board the aircraft.

Primary emphasis of the C-130's survivability in a combat environment are highly dependent upon pre-mission planning and aircrew coordination. Often times the heart of this coordination, as well as pre-mission planning, rely heavily upon the navigator.

I would be happy to respond to any further questions and recommend for you to obtain a Tactical Flight with a C-130 unit for a more complete understanding of our mission and the essential role of the navigator.

16. Captain, 1501-2000 C-130 flying hours, less than 100 combat hours:

The only new piece of technology in the C-130 is SCNS (Self Contained Navigation System). The system is great as far as enhancing our navigation abilitites but in no way will replace any crew member. I'm fairly new to SCNS but it seems to increase (increases workload, but navigation becomes more exacting and more reliable) the flight deck workload. I feel that technology should be used to enhance what a <u>full</u> crew can do and can be used to make results much more precise.

Appendix C: SAS Computer Program

```
options linesize=80;
data temp;
     infile survey1 missover;
     input     @1 (Q1-Q80) (80*1.);
     Q1=Q1+1;
     Q2=Q2+1;
     Q3=Q3+1;
     Q4=Q4+1;
     Q5=Q5+1;
     Q6=Q6+1;
     Q10=Q10+1;
     Q11=Q11+1;
     Q12=Q12+1;
     Q13=Q13+1;
     Q14=Q14+1;
     Q16=Q16+1;
     Q17=Q17+1;
     Q18=Q18+1;
     Q19=Q19+1;
     Q20=Q20+1;
     Q21=Q21+1;
     Q22=Q22+1;
     Q23=Q23+1;
     Q24=Q24+1;
     Q25=Q25+1;
     Q26=Q26+1;
     Q27=Q27+1;
     Q28=Q28+1;
     Q29=Q29+1;
     Q30=Q30+1;
     Q31=Q31+1;
     Q32=Q32+1;
     Q33=Q33+1;
     Q34=Q34+1;
     Q35=Q35+1;
     Q36=Q36+1;
     Q37=Q37+1;
     Q38=Q38+1;
     Q39=Q39+1;
     Q40=Q40+1;
     Q41=Q41+1;
     Q42=Q42+1;
     Q43=Q43+1;
     Q44=Q44+1;
     Q45=Q45+1;
     Q46=Q46+1;
     Q47=5-Q47;
```

```
     Q48=5-Q48;
     Q50=Q50+1;
     Q51=5-Q51;
     Q53=5-Q53;
     Q54=5-Q54;
     Q57=5-Q57;
     Q58=5-Q58;
     Q62=Q62+1;
     Q63=5-Q63;
     Q65=5-Q65;
     Q66=5-Q66;
     Q67=5-Q67;
     Q68=Q68+1;
     Q73=5-Q73;
     Q78=Q78+1;
     Q79=Q79+1;
     Q80=Q80+1;
     If Q1=. then Delete;
     If Q2=6 then Q2=5;
     If Q3=6 then Q3=5;
     If Q2=7 or Q2=8 or Q2=9 or Q2=10 then Q2=Q2-1;
     If Q3=7 or Q3=8 or Q3=9 or Q3=10 then Q3=Q3-1;
     If Q4=2 then Q4=0;
     If Q4=3 then Q4=.;
     If Q5=2 or Q5=3 or Q5=4 then Q5=1;
     If Q5=. then Q5=0;
     If Q6=3 or Q6=6 then Q6=.;
     If Q7=1 or Q7=2 or Q7=3 or Q7=4 or Q7=5 or Q7=6 or Q7=7
     then Q7=Q7+2;
     If Q8=1 or Q8=2 or Q8=3 or Q8=4 or Q8=5 or Q8=6 or Q8=7
     then Q8=Q8+2;
     If Q9=1 or Q9=2 or Q9=3 or Q9=4 or Q9=5 or Q9=6 or Q9=7
     then Q9=Q9+2;
     If Q9=. then Q9=0;
     If Q10=2 then Q10=0;
     If Q11=2 then Q11=0;
     If Q12=2 then Q12=0;
     If Q13=2 then Q13=0;
     If Q80=6 then Q80=.;
     Req=Q48+Q53+Q54+Q66+Q67;
     Navcrit=Q47+Q50+Q51+Q57+Q58+Q62+Q63+Q73;
Proc Format;
     Value Q1fmt    1='A-10'
                    2='B-52'
                    3='C-130'
                    4='F-15E'
                    5='F-16'
                    6='KC-135';
Proc Sort data=temp out=Sordid;
     Format Q1 Q1fmt.;
     by Q1;
     run;
Proc Print Data=Sordid;
```

```
     Format Q1 Q1fmt.;
     Title 'Print-out of Data Base with ALL Recoding';
     run;
Proc Format;
     Value Q1fmt    1='A-10'
                    2='B-52'
                    3='C-130'
                    4='F-15E'
                    5='F-16'
                    6='KC-135';
     Value Timefmt  1='< 250'
                    2='251-500'
                    3='501-750'
                    4='751-1,000'
                    5='1,001-1,500'
                    6='1,501-2,000'
                    7='2,001-2,500'
                    8='2,501-3,000'
                    9='3,001+';
     Value Warfmt   0='None'
                    3='< 100'
                    4='101-200'
                    5='201-300'
                    6='301-400'
                    7='401-500'
                    8='501-1,000'
                    9='1,001+';
     Value Q4fmt    1='Other A/C Qual';
     Value Q10fmt   1='IP';
     Value Q11fmt   1='Evaluator';
     Value Q12fmt   1='Tactics';
     Value Q13fmt   1='Exer. Partic.';
     Value Q14fmt   1='2Lt'
                    2='1Lt'
                    3='Captain'
                    4='Major'
                    5='Lt Col'
                    6='Colonel';
Proc Sort data=temp out=Sordid;
     Format Q1 Q1fmt.;
     by Q1;
     run;
Proc Freq Data=Sordid;
     Format Q1 Q1fmt.;
     Format Q2 Q3 Timefmt.;
     Format Q4 Q4fmt.;
     Format Q7 Q8 Q9 Warfmt.;
     Format Q10 Q10fmt.;
     Format Q11 Q11fmt.;
     Format Q12 Q12fmt.;
     Format Q13 Q13fmt.;
     Format Q14 Q14fmt.;
     Title 'Frequency Print-Out with ALL Recoding';
```

```
    run;
Proc Freq Data=Sordid;
    Format Q1 Q1fmt.;
    Format Q2 Q3 Timefmt.;
    Format Q4 Q4fmt.;
    Format Q7 Q8 Q9 Warfmt.;
    Format Q10 Q10fmt.;
    Format Q11 Q11fmt.;
    Format Q12 Q12fmt.;
    Format Q13 Q13fmt.;
    Format Q14 Q14fmt.;
    By Q1;
    Title 'Frequency Print-Out BY AIRCRAFT with ALL
    Recoding';
    run;
Proc Means Data=Sordid;
    Format Q1 Q1fmt.;
    Var Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23 Q24 Q25 Q26 Q27 Q28
        Q29 Q30 Q31 Q32 Q33 Q34 Q35 Q36 Q37 Q38 Q39 Q40 Q41
        Q42 Q43 Q44 Q45 Q46;
    by Q1;
    Title 'Means of Suggested Critical Mission
          Factors--Sorted By Aircraft';
    run;
Proc Corr Alpha Nocorr;
    Var Q48 Q53 Q54 Q66 Q67;
    Title 'Reliability Test of REQ Using Chronbachs Alpha';
    run;
Proc Corr Alpha Nocorr;
    Var Q47 Q50 Q51 Q57 Q58 Q62 Q63 Q73;
    Title 'Reliability Test of NAVCRIT Using Chronbachs
          Alpha';
    run;
Proc Factor Data=Sordid Scree Meineigen=0 Score;
    Var Q47 Q50 Q51 Q57 Q58 Q62 Q63 Q68 Q73 Q78 Q79 Q80;
    Title 'Factor Analysis of Proposed NAVCRIT Variables';
    run;
Proc Factor Data=Sordid Scree Meineigen=0 Score;
    Var Q48 Q53 Q54 Q65 Q66 Q67;
    Title 'Factor Analysis of Proposed REQ Variables';
    run;
Proc Reg Data=Sordid;
    Model Navcrit=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12
                  Q13 Q14/Selection=Stepwise AdjRsq;
    Title 'Stepwise Reg. of NAVCRIT & R Square--Entire
          Sample';
    Model REQ=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13
              Q14/Selection=Stepwise AdjRsq;
    Title 'Stepwise Reg. of REQ & R Square--Entire Sample';
    run;
Proc GLM Data=Sordid;
    Format Q1 Q1fmt.;
    Class Q1;
```

```
     Model NAVCRIT=Q1 Q6 Q4 Q12 Q1*Q6 Q1*Q4 Q1*Q12 Q6*Q4
                 Q6*Q12 Q4*Q12;
     Means Q1/LSD BON SCHEFFE;
     Title 'Means Comparison By Aircraft of NAVCRIT';
     run;
Proc GLM Data=Sordid;
     Format Q1 Q1fmt.;
     Class Q1;
     Model REQ=Q1 Q6 Q14 Q9 Q1*Q6 Q1*Q14 Q1*Q9 Q6*Q14 Q6*Q9
             Q14*Q9;
     Means Q1/LSD BON SCHEFFE;
     Title 'Means Comparison By Aircraft of REQ';
     run;
Proc Reg Data=Sordid;
     Format Q1 Q1fmt.;
     Model Navcrit=Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13
                 Q14/Selection=Stepwise AdjRsq;
     By Q1;
     Title 'Stepwise Reg. of NAVCRIT & R Square--By
           Aircraft';
     Model REQ=Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13
             Q14/Selection=Stepwise AdjRsq;
     By Q1;
     Title 'Stepwise Reg. of REQ & R Square--By Aircraft';
     run;
ENDSAS;
```

Appendix D: Aircraft Mission Effectiveness Factors

Means of Suggested Critical Mission Factors--Sorted By Aircraft

---------------------------------- Q1=A-10 ----------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
Q16	70	2.2285714	0.9195372	1.0000000	4.0000000
Q17	71	1.9154930	0.9372677	1.0000000	4.0000000
Q18	71	2.4788732	1.0121992	1.0000000	5.0000000
Q19	71	1.9436620	0.9544980	1.0000000	4.0000000
Q20	71	2.7746479	0.7210544	1.0000000	4.0000000
Q21	71	2.2676056	0.9095956	1.0000000	5.0000000
Q22	71	4.0000000	1.1338934	1.0000000	5.0000000
Q23	71	1.5070423	0.6734398	1.0000000	3.0000000
Q24	71	2.0281690	0.8778518	1.0000000	5.0000000
Q25	71	2.3661972	0.9597535	1.0000000	5.0000000
Q26	71	2.4507042	0.9825438	1.0000000	5.0000000
Q27	71	2.6056338	0.7649253	1.0000000	4.0000000
Q28	71	1.2535211	0.6911338	1.0000000	5.0000000
Q29	71	1.6197183	0.7043984	1.0000000	3.0000000
Q30	71	2.2112676	0.8266195	1.0000000	4.0000000
Q31	70	3.5428571	1.6302015	1.0000000	5.0000000
Q32	71	2.2535211	0.9959677	1.0000000	5.0000000
Q33	71	1.6760563	0.8413365	1.0000000	5.0000000
Q34	71	2.5633803	1.0519695	1.0000000	5.0000000
Q35	71	2.6760563	1.0250386	1.0000000	5.0000000
Q36	67	4.2238806	1.3687076	1.0000000	5.0000000
Q37	71	1.6760563	0.8581483	1.0000000	4.0000000
Q38	71	1.2535211	0.5786267	1.0000000	4.0000000
Q39	71	1.0985915	0.3445465	1.0000000	3.0000000
Q40	70	2.1000000	1.4461343	1.0000000	5.0000000
Q41	71	2.8169014	0.7232834	1.0000000	5.0000000
Q42	69	4.4492754	0.9931565	1.0000000	5.0000000
Q43	70	3.8000000	1.1746106	1.0000000	5.0000000
Q44	71	2.6197183	1.1509772	1.0000000	5.0000000
Q45	71	3.2676056	1.0135898	1.0000000	5.0000000
Q46	71	2.2112676	1.0943425	1.0000000	5.0000000

Means of Suggested Critical Mission Factors--Sorted By Aircraft

---------------------------------- Q1=B-52 ----------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
Q16	83	1.7710843	0.8600241	1.0000000	5.0000000
Q17	83	1.6385542	0.8201474	1.0000000	4.0000000
Q18	83	1.9879518	0.9172331	1.0000000	4.0000000
Q19	83	1.7469880	0.8673393	1.0000000	4.0000000
Q20	83	2.6265060	0.7107338	1.0000000	5.0000000
Q21	83	1.7349398	0.8422435	1.0000000	4.0000000
Q22	83	1.8433735	0.8334754	1.0000000	3.0000000
Q23	83	1.3614458	0.5314112	1.0000000	3.0000000
Q24	83	2.5662651	0.8292337	1.0000000	5.0000000
Q25	83	1.6626506	0.8156564	1.0000000	4.0000000
Q26	83	2.5180723	0.9154693	1.0000000	5.0000000
Q27	83	3.8795181	0.9025383	2.0000000	5.0000000
Q28	83	1.6024096	0.7954100	1.0000000	4.0000000
Q29	83	1.4096386	0.6055867	1.0000000	4.0000000
Q30	83	2.1566265	0.7883593	1.0000000	3.0000000
Q31	83	2.7228916	0.8598533	1.0000000	4.0000000
Q32	83	2.1325301	0.9470247	1.0000000	4.0000000
Q33	83	2.4939759	0.9156298	1.0000000	4.0000000
Q34	83	1.8192771	0.9518221	1.0000000	4.0000000
Q35	83	2.2048193	0.8801197	1.0000000	4.0000000
Q36	83	1.5060241	0.6874040	1.0000000	3.0000000
Q37	83	1.7831325	0.7333218	1.0000000	3.0000000
Q38	83	1.3734940	0.6572456	1.0000000	3.0000000
Q39	83	1.7951807	0.9847500	1.0000000	4.0000000
Q40	83	2.9518072	0.8958388	1.0000000	5.0000000
Q41	83	1.9759036	0.8111405	1.0000000	5.0000000
Q42	81	3.5308642	1.3331018	1.0000000	5.0000000
Q43	83	2.9036145	0.8206847	1.0000000	4.0000000
Q44	83	2.4457831	0.7691143	1.0000000	4.0000000
Q45	80	4.4625000	0.9405594	1.0000000	5.0000000
Q46	83	1.7951807	0.7926343	1.0000000	4.0000000

Means of Suggested Critical Mission Factors--Sorted By Aircraft

Q1=C-130

Variable	N	Mean	Std Dev	Minimum	Maximum
Q16	57	2.0175439	0.7903713	1.0000000	3.0000000
Q17	56	1.3214286	0.5754727	1.0000000	3.0000000
Q18	57	2.3333333	1.0578505	1.0000000	5.0000000
Q19	57	1.6842105	0.8484838	1.0000000	4.0000000
Q20	57	2.6842105	0.7357672	1.0000000	4.0000000
Q21	57	1.8596491	0.6927841	1.0000000	3.0000000
Q22	57	2.0526316	0.7658108	1.0000000	3.0000000
Q23	57	1.4385965	0.7323530	1.0000000	3.0000000
Q24	57	2.1578947	0.7970811	1.0000000	4.0000000
Q25	57	1.7017544	0.7310685	1.0000000	3.0000000
Q26	57	2.3508772	0.8343352	1.0000000	4.0000000
Q27	56	4.1428571	0.8618916	2.0000000	5.0000000
Q28	54	4.5370370	0.9850383	1.0000000	5.0000000
Q29	57	2.1403509	1.0253675	1.0000000	4.0000000
Q30	57	2.0000000	0.7319251	1.0000000	4.0000000
Q31	57	2.4035088	0.8631266	1.0000000	4.0000000
Q32	57	1.8245614	0.8045142	1.0000000	4.0000000
Q33	57	1.9649123	0.8444126	1.0000000	4.0000000
Q34	57	2.4561404	0.7575849	1.0000000	4.0000000
Q35	57	2.1052632	0.7484319	1.0000000	3.0000000
Q36	57	1.2456140	0.4342770	1.0000000	2.0000000
Q37	57	1.7368421	0.8134213	1.0000000	4.0000000
Q38	57	1.3333333	0.6074929	1.0000000	3.0000000
Q39	56	1.9464286	1.3269191	1.0000000	5.0000000
Q40	57	1.9122807	0.8717942	1.0000000	5.0000000
Q41	57	2.3157895	0.8692750	1.0000000	5.0000000
Q42	56	3.4821429	1.0615781	1.0000000	5.0000000
Q43	57	2.6491228	0.6941394	1.0000000	4.0000000
Q44	57	2.1403509	0.7662198	1.0000000	3.0000000
Q45	57	2.2807018	0.8609460	1.0000000	4.0000000
Q46	57	1.7543860	0.8717942	1.0000000	5.0000000

Means of Suggested Critical Mission Factors--Sorted By Aircraft

---------------------------------- Q1=F-15E --------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
Q16	53	2.1509434	0.8411582	1.0000000	4.0000000
Q17	53	1.3584906	0.5914240	1.0000000	3.0000000
Q18	53	1.5471698	0.6952044	1.0000000	3.0000000
Q19	53	2.0377358	0.9600133	1.0000000	4.0000000
Q20	53	2.6226415	0.7652655	1.0000000	4.0000000
Q21	53	2.3773585	0.7132379	1.0000000	4.0000000
Q22	53	2.2075472	0.7167901	1.0000000	4.0000000
Q23	53	1.4528302	0.6065678	1.0000000	3.0000000
Q24	53	2.3018868	0.7489712	1.0000000	4.0000000
Q25	53	2.1886792	0.9210488	1.0000000	4.0000000
Q26	53	2.4339623	0.7968552	1.0000000	4.0000000
Q27	53	2.8490566	0.7941184	1.0000000	5.0000000
Q28	53	1.3773585	0.6571036	1.0000000	3.0000000
Q29	53	1.5283019	0.6386215	1.0000000	3.0000000
Q30	53	1.8301887	0.8712469	1.0000000	4.0000000
Q31	53	3.0188679	1.0093899	1.0000000	5.0000000
Q32	53	2.5660377	0.9095526	1.0000000	4.0000000
Q33	53	1.6792453	0.7009221	1.0000000	3.0000000
Q34	53	2.7547170	0.7313228	1.0000000	4.0000000
Q35	53	2.4905660	0.7499395	1.0000000	4.0000000
Q36	53	1.7547170	0.6766905	1.0000000	3.0000000
Q37	53	1.6037736	0.7162837	1.0000000	3.0000000
Q38	53	1.1886792	0.3949977	1.0000000	2.0000000
Q39	53	1.3584906	0.5914240	1.0000000	3.0000000
Q40	53	2.7924528	0.7932041	1.0000000	5.0000000
Q41	53	1.9245283	0.7298329	1.0000000	3.0000000
Q42	51	3.3333333	1.3515423	1.0000000	5.0000000
Q43	52	3.2115385	0.9566391	1.0000000	5.0000000
Q44	53	2.0377358	0.8540011	1.0000000	4.0000000
Q45	52	4.3076923	0.9130460	1.0000000	5.0000000
Q46	53	2.0377358	0.7835389	1.0000000	4.0000000

Means of Suggested Critical Mission Factors--Sorted By Aircraft

Q1=F-16

Variable	N	Mean	Std Dev	Minimum	Maximum
Q16	74	2.5135135	0.7260938	1.0000000	4.0000000
Q17	74	1.2432432	0.6985466	1.0000000	5.0000000
Q18	74	1.7567568	0.8728918	1.0000000	4.0000000
Q19	74	1.7567568	1.0311692	1.0000000	5.0000000
Q20	74	2.4459459	0.8462956	1.0000000	4.0000000
Q21	74	2.5945946	0.7006635	1.0000000	4.0000000
Q22	74	3.1621622	0.9934998	1.0000000	5.0000000
Q23	74	1.5540541	0.7610716	1.0000000	5.0000000
Q24	74	2.1621622	0.8605036	1.0000000	4.0000000
Q25	74	2.1351351	0.7993889	1.0000000	3.0000000
Q26	74	2.5540541	0.7050093	1.0000000	4.0000000
Q27	74	3.0810811	0.6974858	1.0000000	4.0000000
Q28	74	1.4054054	0.8095140	1.0000000	5.0000000
Q29	74	1.5405405	0.7250732	1.0000000	4.0000000
Q30	74	1.9189189	0.8235699	1.0000000	4.0000000
Q31	74	3.1216216	1.62[illegible]7971	1.0000000	5.0000000
Q32	74	2.2567568	0.9517225	1.0000000	4.0000000
Q33	74	1.6216216	0.8391565	1.0000000	5.0000000
Q34	74	2.4189189	0.7764824	1.0000000	4.0000000
Q35	74	2.5405405	0.8788097	1.0000000	5.0000000
Q36	73	3.8493151	1.4109811	1.0000000	5.0000000
Q37	74	1.7432432	0.8768063	1.0000000	4.0000000
Q38	74	1.4054054	0.7749312	1.0000000	5.0000000
Q39	74	1.3643643	0.7323134	1.0000000	5.0000000
Q40	74	2.3648649	0.9732635	1.0000000	5.0000000
Q41	74	2.9324324	0.8653304	1.0000000	5.0000000
Q42	71	3.5492958	1.3500130	1.0000000	5.0000000
Q43	73	3.2191781	1.1334139	1.0000000	5.0000000
Q44	73	2.2465753	0.9686379	1.0000000	5.0000000
Q45	73	4.0958904	1.1324063	1.0000000	5.0000000
Q46	73	2.4246575	0.9706500	1.0000000	5.0000000

Means of Suggested Critical Mission Factors--Sorted By Aircraft

---------------------------------- Q1=KC-135 ----------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
Q16	65	2.0461538	0.9088243	1.0000000	4.0000000
Q17	66	2.2121212	0.9201196	1.0000000	4.0000000
Q18	66	2.6060606	1.0506963	1.0000000	5.0000000
Q19	66	1.7575758	0.8423521	1.0000000	4.0000000
Q20	66	2.7878788	0.6205494	1.0000000	4.0000000
Q21	65	4.2461538	0.8297358	1.0000000	5.0000000
Q22	65	4.3384615	0.8710074	1.0000000	5.0000000
Q23	66	2.5909091	1.0521374	1.0000000	5.0000000
Q24	65	2.4307692	0.7493587	1.0000000	4.0000000
Q25	65	3.1076923	1.5423509	1.0000000	5.0000000
Q26	66	2.5454545	0.7270979	1.0000000	4.0000000
Q27	65	4.3230769	1.0324076	2.0000000	5.0000000
Q28	64	4.7500000	0.8164966	1.0000000	5.0000000
Q29	66	3.0606061	1.1215208	1.0000000	5.0000000
Q30	66	2.6212121	0.7393376	1.0000000	4.0000000
Q31	66	3.0000000	1.0076629	1.0000000	5.0000000
Q32	66	2.3787879	0.9074928	1.0000000	4.0000000
Q33	66	2.7272727	0.8328903	1.0000000	5.0000000
Q34	66	2.3636364	0.9709054	1.0000000	4.0000000
Q35	66	2.6515152	0.7543193	1.0000000	4.0000000
Q36	66	2.0606061	0.8749292	1.0000000	4.0000000
Q37	65	3.0000000	0.9842510	1.0000000	5.0000000
Q38	66	1.9090909	0.8544413	1.0000000	5.0000000
Q39	64	4.5937500	0.9209855	1.0000000	5.0000000
Q40	63	4.8095233	0.6134565	2.0000000	5.0000000
Q41	66	2.7424242	0.9657298	1.0000000	5.0000000
Q42	63	4.8412698	0.5449578	3.0000000	5.0000000
Q43	65	2.3846154	0.9133097	1.0000000	5.0000000
Q44	66	2.5909091	0.8766593	1.0000000	5.0000000
Q45	65	4.4461538	0.9359232	1.0000000	5.0000000
Q46	63	4.2063492	1.2463978	1.0000000	5.0000000

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Vita

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1991

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
A STUDY OF PILOT ATTITUDES REGARDING THE IMPACT ON MISSION EFFECTIVENESS OF USING NEW COCKPIT AUTOMATION TECHNOLOGIES TO REPLACE THE NAVIGATOR/WEAPON SYSTEM OFFICER/ELECTRONIC WARFARE OFFICER

5. FUNDING NUMBERS

6. AUTHOR(S)
WILLIAM K. STARR, Major, USAF and
DONALD A. WELCH, Major, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GLM/LSR/91S-62

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
ASD/EN, WPAFB OH 45433-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This study analyzed the self-reported survey responses of 404 Air Force pilots concerning their perceptions of using advanced cockpit technologies to replace the Navigator, Weapon System Officer, and Electronic Warfare Officer (Nav/WSO/EWO) and the impact of advanced cockpit technologies on combat mission effectiveness. The first objective of this study was to compare, by aircraft type, the mission effectiveness factors that are always critical and almost always critical to the success of a combat mission. The second objective was to examine, from the pilot's point of view, the Nav/WSO/EWO's contribution (NAVCRIT) to enhancing the combat mission effectiveness factors. The third objective was to examine the Nav/WSO/EWO's contribution (REQ) to overall combat mission success. A stepwise regression model for predicting NAVCRIT and REQ utilizing surveyed pilot demographics was also explored. Research conclusions were mixed—aircraft type impacted on almost all results. Mission effectiveness factors that were always critical were, however, similar across all aircraft types. Examination of NAVCRIT and REQ revealed distinct differences, by aircraft type, of the pilot's perception of Nav/WSO/EWO contribution to combat mission effectiveness.

14. SUBJECT TERMS
Cockpits, Combat Effectiveness, Navigators, Pilots

15. NUMBER OF PAGES
257

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
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